Update of Statistical Framework for the Onondaga Lake Ambient Monitoring Program Phase II–Biological Monitoring

prepared for

Department of Water Environment Protection

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by

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Introduction

The Onondaga Lake Ambient Monitoring Program (AMP) has been designed to provide information supporting future decisions on wastewater and watershed management (Onondaga County, 1998). These decisions will be based in part upon changes detected in the Lake, its tributaries, and the Seneca River following implementation of point and non-point source control measures over the next several years. Decisions will also rely upon comparisons of monitored conditions with water quality standards or management goals. The ability to detect such changes and the reliability of such comparisons depend in part upon the design of the monitoring program. Decisions should not be made based upon the monitoring results without an adequate understanding of the sources and magnitudes of variability in the data.

Previous reports (Walker, 1998; 1999; 2000; 2002) describe a statistical framework with the following functions under the AMP:

- Identifying and quantifying sources of variability in the data;
  Evaluating uncertainty associated with summary statistics;
- Formulating and testing specific hypotheses; and
  Refining monitoring program designs;

The framework has been implemented in two phases. One series of reports (Phase I, Walker 1999; 2002) evaluates sampling program designs for water quality components (phosphorus, nitrogen, Kjeldahl nitrogen, ammonia, chlorophyll-a, transparency, & bacteria). This report updates the Phase II effort (Walker, 2000) evaluating sampling program designs for the following biological measurements:

- Plankton
- Macrophytes
- Macroinvertebrates
  Fish

The initial Phase II report evaluated sampling designs using variance component models calibrated to limited historical data from Onondaga Lake, other regional lakes, and the general literature. This report updates that analysis using extensive biological monitoring data collected under the AMP in year 2000 (EcoLogic, 2001ab; EcoLogic et al., 2001; Icththyological & EcoLogic, 2001). The recalibrated framework is used to evaluate proposed monitoring designs for 2002 and subsequent years (Table 1).

Objectives

Measurement precision is important because it partially controls the power for detecting long-term trends or step changes resulting from implementation of management measures. The AMP scoping report (Onondaga County, 1998, p. 39) established a benchmark (RSE< 20%, RSE = relative standard error = standard error/mean) for evaluating the precision of yearly population means measured under the monitoring program. Precision depends upon (1) inherent variations in the populations, (2) inherent variations in sampling, and (3) monitoring program design (spatial & temporal monitoring frequency, replication). The first factor imposes a limit on the precision that is practically achievable by improving sampling methods & increasing sampling frequency. Power for detecting trends is also limited by the inherent random year-to-year variability in the populations and the overall duration of the monitoring program. These factors function as constraints.

The statistical framework (Walker, 1998) expresses the above concepts in mathematical terms. Variance component models are used to evaluate the sensitivity of precision and power to monitoring frequency, given the inherent variability of the populations. Calibration involves estimating spatial and temporal variance components using historical data from Onondaga, other regional lakes, and the general literature.

Previous analyses (Walker, 1999; 2001) have shown that the 20% RSE criterion can be achieved for water quality parameters using the reasonably cost-effective monitoring designs currently implemented under the AMP. Because of the greater inherent variability in biological populations, however, this criterion is difficult to achieve for abundance measurements (or relative abundance measurements, such as catch per unit effort). Initial RSE estimates were in the range of 20 to 30% for most abundance measurements (Walker, 2000). Greater precision is generally attainable for other indices that describe population distributions and characteristics (species richness, diversity, size distribution, stock density, etc.). The AMP biological monitoring workgroup (BMW) has recommended a shift in focus away from abundance to qualitative indices that can be measured more precisely and are more meaningful measures of ecosystem status. The workgroup has revised monitoring plans that reflect this shift in focus, as well as lessons learned during implementation of the Year 2000 monitoring plan and interpretation of results (Table 1).

For the above reasons, the statistical framework continues to track the precision of abundance measurements, but considers the 20% RSE benchmark primarily in relation to qualitative indices. With future integration of the water quality and biological monitoring, specific goals and performance measures will be developed. This will enable formulation of specific hypotheses to be tested using the data. Precision will be evaluated in relation to the meaningful scale of each parameter. For example, a 20% RSE may provide sufficient resolution for tracking a parameter with an overall scale of 1 to 100, but not for one with a scale of 7 to 10.

Another major change recommended by the workgroup is an increase in fish monitoring frequency from biennial (every two years) to annual. This recommendation is consistent with the concept that power for detecting changes or trends is controlled more by random year-to-year variability than by the precision of the measured mean values within each year (Walker, 2000). For a given total level of effort, yearly monitoring provides a more powerful database for detecting trends than biennial monitoring, even if the precision of each yearly measurement is (up to a point) lower. The statistical framework provides a basis for evaluating these tradeoffs.

Evaluation Criteria

Basic statistical concepts and models used in the framework are described in previous report (Walker, 1998, 2000). Depending upon parameter, sampling designs are evaluated based upon the following statistics:

1. Precision of mean values for a given sampling event and sampling unit (station, lake region)

2. Precision of lake-mean values for a given sampling event (for parameters with spatially-stratified sampling designs)

3 Precision of yearly means for each stratum & the entire lake (for parameters that are sampled on multiple dates throughout the growing season)

Precision is expressed in terms of relative standard error (RSE = standard error / mean).

The precision of sampling-unit means (Item 1) depends upon the number of samples collected and variability within the sampling unit. The coefficient of variation (CV = standard deviation / mean) describes variability within the sampling unit. Precision is calculated using the classical statistical formula: $RSE = CV / N^{1/2}$, where N = number of random samples (Snedocor & Cochran, 1989). The sampling unit is defined as a specific site for tributary macroinvertebrates, lake phytoplankton, and lake zooplankton. For parameters in which spatially-integrated estimates are developed, the sampling unit is defined as a specific lake region (i.e., 5 strata for adult fish, juvenile fish, littoral fish larvae, macrophytes, and macroinvertebrates and 2 lake basins for pelagic fish larvae). For two-stage designs (i.e., multiple sites with replication within each lake region), a distinction is made between variation across sites and variation across replicates at a given site when possible; otherwise, precision estimates are based upon the total variation across sites and replicates within a given stratum and the total number of samples.

The precision of a whole-lake estimate (Item 2) for a given sampling event is computed based upon the precision of regional estimates and the total number of regions. It is assumed that fixed variations across lake regions do not influence the precision of whole-lake estimates (the advantage of stratified designs).

The precision of yearly means (Item 3) depends upon the precision of means for each sampling event, variability between events, and the number of events sampled. Variations between events are assumed to be random and fixed seasonal effects are ignored. These two assumptions are likely to result in conservative estimates of precision (i.e., over-estimation of RSE's). Given that most of the populations exhibit strong seasonal variations in quantity and species distribution, the relevance of the "yearly mean" as a measure of ecosystem status is questionable. It seems more likely that data interpretations and evaluations of trends would be based on the seasonal distributions of population characteristics, rather than annual means. For this reason, greater weight is placed on evaluating the precision of mean values per sampling event (Items 1 & 2).

Power for detecting long-term trends or step changes depends upon the precision of yearly mean values, random year-to-year variability, and the duration of the monitoring program (Walker, 2000). Multi-year data sets collected with a consistent protocol would be required to estimate random year-to-year variability. Such data sets do not yet exist for the biological parameters considered here. Year-to-year CV's for water quality parameters measured in the lake epilimnion range 0.06 to 0.3 (Walker, 2002). For the purpose of estimating power, a probable range of 0.1 to 0.3 is assumed for all biological parameters. Even though site-specific estimates of random year-to-year variability are not available for evaluating survey designs, trend analyses and other hypothesis tests performed later in the program when long-term datasets are available will reflect the actual year-to-year variability in the abundance and species distribution of lake and tributary biota.

The following expressions of power are evaluated for each parameter using equations described previously (Walker, 2000):

1. Probability of Detecting Step Increases of 25, 50, & 100%
2. Step Increase Detectable with 80% Confidence (%)
3. Probability of Detecting Linear Trends of 3, 5, and 10 %/yr.
4. Linear Trend Detectable with 80% Confidence (%/yr)

Power for detecting step increases is evaluated for comparing data from two 5-year periods (e.g., 2000-2004 vs. 2005-2009). Power for detecting linear trends is evaluated for a 10-year monitoring interval. These tests are surrogates for the types of hypotheses that are likely to be tested using AMP data near the end of the program.

To reflect uncertainty in variance component estimates, Monte-Carlo simulation techniques (Reckhow & Chapra, 1983) are used to predict the expected ranges of the precision and power criteria for assumed ranges of variance components. Variance component estimates are drawn from uniform distributions with ranges estimated primarily from AMP data collected in Year 2000. The frequency distribution of each predicted criterion is expressed in terms of the 80% confidence interval (10^{th}, 50^{th}, and 90^{th} percentile).

Metrics

The analysis considers abundance and other population indices tabulated in datasets provided by the biological monitoring teams (EcoLogic, 2001ab; EcoLogic et al., 2001; Icththyological & EcoLogic, 2001). The previous report (Walker, 2000) focused primarily on evaluating measures of abundance or relative abundance. The precision of abundance measurements is limited by high inherent spatial & temporal variability of biological populations. Nonrandom spatial distribution (patchiness) is a particular problem in measuring species abundance (Green, 1979). As discussed above (see Introduction), the BMW has recommended a shift in focus away from abundance to qualitative indices that can be measured more precisely and may represent more meaningful indicators of ecosystem health.

Qualitative indices are more sensitive to the composition of the community (species distribution) than to the number of organisms. Examples include NYSDEC and HBI Scores for macro-invertebrate populations (EcoLogic, 2001b). The workgroup has recommended an emphasis on species richness and diversity for fish populations.

Unlike abundance and other qualitative indices, estimates of species richness (total number of species) are dependent upon sample size. As the number of collected samples (or collected organisms) increases, a systematic trend in the average count would not be expected, but the number of detected species would be expected to increase, as increasingly rare species are captured. This characteristic is reflected in Year 2000 fish population data from Onondaga Lake. Correlations between species richness and organism count are shown in Figures 1-4 for littoral larvae, pelagic larvae, juvenile fish, and adult fish, respectively. Each data point reflects an average value computed from multiple samples (sweeps, tows, transects) within a given lake stratum during a given sampling event. Positive correlations between richness and count are evident in each population. In the case of juvenile fish, the trend reverses at high organism counts (>20 captured fish / sweep). This reversal reflects infrequent sampling events when schools of small fish (high density of single species, such as gizzard shad) were captured.

Since Figures 1-4 reflect data from different regions of the lake, it is possible the correlation between richness and abundance is partially attributed to spatial variations, as opposed to a sample-size effect (see comments by Ecologic, Appendix B). Regions of the lake with more favorable habitat would tend to have both higher abundance and higher diversity (consider a corral reef vs. sandy beach, for example). To test for spatial effects, correlations between richness and abundance across individual transects for adult gamefish have been examined with and without subtracting the stratum mean values from each sample (Figure 4A). Removing the stratum means reduces the correlation coefficient from 0.72 to 0.59. Spatial variations at the stratum scale do not appear to explain the correlation, although spatial variations on a finer scale may be contribute.

Because of the positive correlation between abundance and species richness, the factors which limit the precision of abundance measurements also limit the precision of richness measurements. In addition, comparison of species richness data from two periods may be misleading if organism counts are significantly different between the two periods. Potential methods to account for this correlation include:

1 Eliminate samples with low organism counts from the computation of species richness. The correlation between richness and count is less strong in the higher count range. A specific cutoff point would have to be set for each fish category. Information would be lost in the screening process, however.

2. Pool replicate (or multi-site) samples within each stratum (mathematically) until the total count exceeds some pre-defined minimum value and compute species richness from the pooled samples. The number of available samples may be insufficient, however, when population density is low. In addition, pooling samples essentially eliminates replicates and makes it increasingly difficult to estimate precision. This option is not recommended by Ecologic (Appendix B) to preserve the replicates and the capability of testing for spatial variation across strata.

3. Use an alternative index of species composition, such as the Shannon-Weaver diversity index = $-\Sigma p_i \ln p_i$, where p_i = proportion of species i in sample, or normalized species richness =(S-1)/Log(N), where S = number of species, N = total count (Margalef, 1958; Green, 1979). Figures 1-4 suggest that the Shannon-Weaver index is generally independent of abundance, with the exception of juveniles at high abundance levels (possible schooling effect discussed above). It is not clear, however, that species richness and diversity measure the same thing. Richness (number of species) is simpler and easier to explain to the public and decision makers. Species richness has been described as "the only objective measure of diversity" (Poole, 1974; Green, 1979). Normalized richness may be a good compromise, since it also appears to be reasonably independent of abundance for adult fish (Figure 4) and is much simpler than the Shannon Weaver index.

Each of the above has its advantages and limitations. A recommended approach for handling AMP species richness data can be developed based upon future statistical analyses and discussions in the BMW. Meanwhile, extreme caution is recommended in interpreting richness values computed directly from the data without considering the apparent effects of sample size.

As a consequence of the dependence of species count on sample size, richness increases when samples are pooled within and/or across strata. Figure 5 compares pooled richness per stratum (total number of species in stratum) with the average richness per stratum (average of the total number of species collected in each transect within the stratum). Pooling has a much smaller effect on the Shannon-Weaver Index or normalized species richness. Because pooling samples eliminates replication, it is not possible to evaluate precision for pooled samples using the variance component models in the current statistical framework. Larger datasets, more elaborate models that depend upon the expected frequency of rare target species (Greene,1979), and alternative statistical methods, such as bootstrapping (Sprent,1990; Efron & Tibsharani, 1998) would be useful for evaluating precision of pooled samples. This topic is recommended for investigation in future updates of the statistical framework.

Precision estimates are developed below for the Shannon-Weaver diversity index and average species richness (i.e., average number of species per sample within each stratum). The latter is essentially a binary expression of abundance; i.e., the abundance matrix (species x sample) is converted to 0's and 1's before computing variance components and estimating precision.

Results

Table 2 summarizes variance component estimates derived from Year 2000 monitoring data. To reflect variability in CV's within sampling units, the approximate 10th, 50th, and 90th percentile values are listed, along with corresponding RSE estimates for the 2002 monitoring program design. When sufficient data are not available for estimating the 10th and 90th percentiles, the observed range is used. Abundance and other population indices tabulated in datasets provided by the biological monitoring teams are evaluated. Based upon BMW discussions, the analysis excludes fish nests (a whole-lake counting effort considered to have adequate precision for its intended purposes) and adult pelagic fish (limited data available from experimental gill nets).

Figure 6 shows that the variability of adult fish population measurements is reasonably consistent with data from other lakes used in the previous analysis (Walker, 2000). The expected negative correlation between within-stratum CV's and relative abundance (Walker, 2000, Table 3) is also apparent for pelagic larvae (Figure 2), but not for littoral larvae (Figure 1) or juveniles (Figure 3). The pattern is evident for littoral larvae and juveniles, however, when data from individual species are considered. Variance can be stabilized by transforming the abundance data, using the ln(1+Count) expression, for example (Green, 1979).

Median precision estimates for fish abundance, richness, and diversity are compared for each fish category in Figure 7. These statistics refer to lake-mean values per sampling event. Species richness and diversity estimates have consistently better precision than the abundance measurements. For reasons stated above (see Metrics), it is possible that RSE's of species richness and diversity indices developed from pooled replicate samples within each stratum (or over the entire lake) would be higher than those shown. Since diversity is less sensitive to species counts (Figures 1-4) and pooling (Figure 5), the RSE estimates for diversity are probably more accurate than the estimates for richness.

Monte-Carlo simulations have been performed to estimate the uncertainty associated with precision and power estimates for a subset of measurements and indices. Worksheets for each analysis are listed in Appendix A. Each worksheet contains a summary of the AMP design, variance component estimates, and evaluation criteria for each spatial scale. Results are summarized over all parameters in Table 3 and displayed in the following figures:

Figure 8	Precision of Means
Figure 9	Increases Detectable with 80% Confidence
Figure 10	Trends Detectable with 80% Confidence
Figure 11	Sensitivity of Precision to Increases in Sampling Frequency

Results summarized in the above figures refer to the largest relevant spatial scale for each parameter, as described in Table 3 (station for tributary and littoral macroinvertebrates, phytoplankton, & zooplankton and lake for the remaining parameters). Precision estimates for fish populations are summarized on a sampling-event basis. Results for other spatial and temporal scales are listed in the Appendix A worksheets A. Results for water quality variables (Walker, 2002) are presented for comparison with the biological variables. Except were noted, the RSE values discussed below refer to 50th percentile estimates.

Median RSE estimates are below the 20% benchmark for most of the indices. RSE's are in the 20-30% range for pelagic larvae richness, macrophyte cover, phytoplankton, zooplankton, chlorophyll-a, and fecal coliforms. The RSE estimate for pelagic larvae abundance is 35%.

The low precision of the pelagic larvae abundance measurements reflects high variance in these populations and the decrease in sampling frequency relative to original program design, as implemented in 2000. The original design for pelagic larvae involved 3 depths and 6 replicates in each lake basin, as compared with 4 depth-integrated tows in each basin under the current design. This change was recommended by the BMW, based upon the high cost of processing pelagic larvae samples and the shift in emphasis away from abundance to richness and diversity indices. Despite the high RSE of abundance, the RSE for pelagic larvae richness (median = 21%, confidence range = 10% to 32%) is reasonably consistent with the AMP objective.

Under current AMP designs for most biological parameters, there would be >80% chance of detecting a statistically significant ($p<.05$) increase (or decrease) of 40-70% (Figure 9), using a t-test comparing average values in the first 5 vs. last 5 years of monitoring. Similarly, there would be >80% chance of detecting a trend of 6-12 %/yr based upon a linear regression using data from 10 years of monitoring (Figure 10). Probabilities of detecting step increases or trends of specific magnitudes are listed on the worksheets in Appendix A. These estimates assume that random year-to-year variability(CV) is in the range of 10-30% for each parameter (typical of chlorophyll-a and water quality variables). Direct estimates of year-year variability for biological parameters can be derived from future AMP data.

The power of juvenile and pelagic larvae abundance data is relatively low (detectable change ~90% vs. <70% for other parameters). As estimated here, power depends on the RSE of the yearly means, which are also relatively high for these parameters. The median RSE for lakewide pelagic larval abundance on a given sampling date is 35%, as compared with 50% for the yearly-mean lakewide abundance (Appendix A-10). Corresponding values for juvenile fish are 14% and 49%, respectively (Appendix A-12). Variability between sampling events over the season contributes substantially to the low precision of the yearly-mean values for these parameters. The high temporal variability in juvenile abundance is strongly influenced by the a large catch of 3617 gizzard shad lakewide in August as compared with a range of 1-809 for other species and sampling dates Four out of 45 lakewide samples accounted for 86% of the total gizzard shad catch in August (Ichthy. & EcoLogic, 2001, Table 3.3-1). Given the substantial seasonal variability expected for these parameters, it is not clear that estimates of yearly-mean abundance are any more meaningful than estimates of abundance for each event or season. A statistical procedure that accounts for seasonal variations (such as the Seasonal Kendall Test, Helsel & Hirsch, 1992), as opposed to a linear regression of annual means, would be likely to provide greater power for detecting trends in these parameters, as compared with results shown in Figures 9 and 10.

Figure 11 shows the effect of increasing sampling intensity on the RSE values for each parameter. Doubling the number of samples per stratum or site would reduce the RSE of mean values per sampling event by ~30%. There would be less impact on the precision of yearly-mean values (phytoplankton, zooplankton), which are controlled partially by random variations between sampling events. With the exception of pelagic larval richness, RSE values for richness and other indices of species distribution (e.g., invertebrate NYSDEC scores) are consistent with the 20% AMP objective.

Doubling sampling intensity for pelagic larvae would reduce the median RSE estimate from 21% to 15%. This change is small relative to the confidence range for the existing design (10 – 32%, Table 3, Figure 8). Reductions in variability may result from recent improvements in the sampling procedure (depth integrated tows in 2002 vs. discrete samples in 2000). Analysis of the 2002 data would provide a better basis for recommending any changes in the current design.

A detailed discussion of each dataset is beyond the scope of this report. Specific characteristics of the year 2000 lake macrophyte and adult fish datasets are discussed below, as they pertain to sampling design.

Macrophyte Data

A three-stage sampling design was used for macrophytes (EcoLogic, 2001a). For measuring percent cover & species distribution, the design involved ~1200 subplots distributed along 20 transects in 5 strata. Only 23 subplots were sampled for macrophyte biomass. The cover data strongly suggest that subplot measurements along a given transect are nonrandom (serially correlated with distance from shore). Therefore, precision has been estimated by averaging along each transect first, then evaluating variability across transects within each stratum. Estimates of stratum means are based upon an average of 4 transects per stratum. Median RSE estimates for lakewide average densities out to the end of growth are 20% for cover and 31% for biomass (Table 2). The RSE estimate for average percent cover out to 4 meters depth is 23% (biomass not computed because of limited data). Precision for occurrence frequency (% of subplots with plants) is somewhat better (RSE = 15% for 4-meters and 19% for end of growth estimates).

It is recommended that the BMW develop a consensus on the appropriate averaging method for macrophyte data. To compute lakewide coverage, the average cover out to the end of growth in each stratum would have to be multiplied by the average distance from shoreline out to the end of growth. The average percent cover out to a fixed water depth (say, 4 meters or some other fixed distance) would be proportional to the total cover, provided that the maximum depth exceeds the average photic zone depth. The potential relevance of macrophyte species richness or diversity should also be considered. Since only one additional detailed macrophyte survey is scheduled under the AMP, it is likely that evaluation of trends will be based more on interpretation of yearly aerial photographs and corresponding field measurements, as compared with the detailed surveys.

Adult Fish Data

Figures 12 and 13 show the spatial and temporal distribution of adult gamefish and total fish, respectively, using each of three metrics: relative abundance (catch/effort), species richness, and species diversity (Shannon-Weaver index). Means and standard errors are plotted as a function of lake stratum (1-5) and sampling event (May, September, October). Lake strata are sorted in north to south direction. Although it is beyond the scope of this report to interpret the data, these results are relevant to the evaluation of the sampling program design and selection of appropriate metrics for measuring fish populations.

The displays suggest a general north to south decreasing trend for some metrics and seasons. The challenge in interpreting these data will be to sort out potential effects of water quality, macrophyte cover, wind energy, and recruitment from the Seneca River, all of which exhibit north-to-south trends. On the average, spatial variations tend to be stronger than temporal variations and stronger in the fall than in the spring. The apparent north-south spatial trends are stronger for gamefish indices (Figure 12) than for total fish indices (Figure 13). The weaker signal for total fish partially reflects the fact that the number of replicates per stratum averages 2.4, as opposed to 4.8 for gamefish, because nongame fish are counted every-other transect. Patchy distribution also contributes to greater variability in the total fish vs. gamefish data. For example, a total of 625 gizzard shad were collected in a single 15-minute transect (May, Stratum 4), as compared with a range of 0 to 38 for all other transects on the same date. Similarly, 1022 gizzard shad were collected in a single transect (September, Stratum 1), as compared with a range of 0 to 48 for the other transects. These samples have large influences on stratum and lake-wide estimates of total fish abundance and diversity. Use of a variance stabilizing transformation in summarizing the data (e.g., ln (1+Count), Green, 1979) will reduce sensitivity to infrequent high-count samples.

Even though precision is lower for abundance measurements, as compared with richness and diversity (Table 2, Figure 12), spatial patterns are no less evident. This reflects the fact that abundance varies over a wider scale, so its signal/noise ratio is similar to that for the other indices. Abundance should not be discounted as an important index for tracking the system, despite relatively low precision.

The relevance of abundance, richness, and diversity indices computed for the total population vs. gamefish only should be considered by the BMW. Consideration should be given to counting the nongame species more frequently if characterizing that the total population is equally or more important than characterizing the gamefish population only.

Conclusions & Recommendations

1 The statistical framework has been recalibrated using extensive biological monitoring data collected in Year 2000 and used to evaluate proposed designs for 2002 and subsequent years. The precision of the current monitoring program satisfies AMP objectives for most parameters. Relative standard error (RSE) estimates are below 20% for most populations and indices. RSE estimates are in the 20-30% range for pelagic larvae richness, macrophyte cover, phytoplankton, and zooplankton.

2. Precision is generally better for measures of species distribution (richness, diversity, NYSDEC scores for invertebrates) than for measurements of abundance or relative abundance. This is compatible with an increased emphasis placed on species distribution measurements vs. abundance measurements by the AMP biological monitoring workgroup.

3. The RSE for pelagic larvae abundance is estimated to be 35% (confidence range 22-48%). This reflects high population variance and a decrease in sampling frequency relative to original program design. The latter change was recommended by the biological monitoring workgroup, based upon the high cost of processing pelagic larvae samples and the shift in emphasis away from abundance towards richness and diversity indices. Despite the high RSE for abundance, the RSE for pelagic larvae richness is close to the AMP objective (21%, confidence range 10-35%). Potential increases in sampling frequency for pelagic larvae should be considered after analysis of the 2002 data collected with improved sampling techniques.

4. The statistical framework also evaluates power for detecting long-term changes or trends in each parameter. Under current AMP designs, there would be >80% chance of detecting a statistically significant ($p<.05$) increase (or decrease) of 40-70% in most parameters. Similarly, there would be >80% chance of detecting a trend of 6-12 %/yr based upon 10 years of monitoring data.

5. Year 2000 fish data demonstrate that species richness (number of species) computed from a given sample is dependent upon sample size (number of organisms counted). This dependence complicates comparisons of richness data from different samples, regions, or time periods. Other indices (normalized richness or Shannon-Weaver diversity index) are less sensitive to sample size and to pooling of samples within strata. Spatial effects related to fish habitat partially explain the apparent correlations between richness and abundance. The

biological monitoring workgroup should develop a standard protocol for computing richness and diversity indices to be used in processing future AMP datasets and interpreting results. Simulation or bootstrapping techniques should be investigated as means of evaluating the precision of richness estimates.

6. Sampling of juvenile and adult fish populations is complicated by patchy distribution. In particular, large samples of gizzard shad collected in a few samples during 2000 had influences on the abundance and diversity indices on a stratum and lakewide basis. Use of logarithmic transformations in summarizing the data would tend to reduce the influence of individual samples.

7. Despite the relatively low precision of abundance measurements, as compared with richness and diversity indices, abundance should not be discounted as an important index for tracking fish populations. Spatial and temporal variations in abundance tend to be larger compared with the other indices, so that the single/noise ratio and probability of detecting significant variations may be similar.

8. The relevance of abundance, richness, and diversity indices computed for the total adult fish population vs. gamefish only should be considered by the biological monitoring workgroup. Consideration should be given to counting the nongame species more frequently if characterizing that the total population is equally or more important than characterizing the gamefish population only.

9. Future updates of the statistical framework should focus on evaluating power for testing specific hypotheses formulated by the biological monitoring workgroup. These hypotheses should focus on populations, spatial scales, temporal scales, and indices that are considered to be most important for tracking changes in the lake ecosystem potentially resulting from water quality improvements.

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12 Spatial & Temporal Distribution of Adult Gamefish, Year 2000 Survey

13 Spatial & Temporal Distribution of Adult Total Fish, Year 2000 Survey

Table 1
AMP Design for Biological Parameters - 2002 & Subsequent Years

Category	Years	Season	Frequency	Dates / Year	Method	Depths	Lake Strata	Sites/Stratum	Samples/Site
Pelagic Larvae	annual	April - MidAug	biweekly	7	miller trawl, double oblique tows, day	0-9 m integral	2 Basins (N/S)	4	1
Littoral Larvae	annual	April - MidAug	biweekly	7	seine	-	5	3	1
Juvenile Fish	annual	May-Oct	every 3 weeks	7	seine	-	5	3	3
Adult Total Fish, Littoral Zone	annual	Spring & Fall	twice	2	electrofishing	< 2 m	5	2.4	1
Adult Gamefish, Littoral Zone	annual	Spring & Fall	twice	2	elecrofishing	< 2 m	5	4.8	1
Adult Fish, Profundal Zone *	annual	Spring & Fall	twice	2	gill nets	4-5 m	5	1	1
Fish Nests *	annual	June	once	1	visual counts, by species	bottom	5	4.8	-
Photoplankton	annual	April-Oct	biweekly /monthly	~18 South, 3 North	tube	epil & pholic zone compos.	2 (N/S)	1	1
Zooplankton	annual	April-Oct	biweekly	~18	net tow	epil & 15 m	2 (N/S)	Lake South + North (4 Dates)	1
Macrophyte Biomass	twice	august	twice	1	harvest	littoral zone	5	~ 4 transects	~6.4
Macrophyte Cover	twice	august	twice	1	observation	littoral zone	5	~ 4 transects	~95
Littoral Macroinvert.	biennial	July	once	1	dredge	3	5	-	36
Tributary Macroinvert	biennial	July	once	1	kick	1	n/a	10	4

* Statistical evaluation not performed for angler census, adult fish in profundal zone (limited 2000 data, experimental sampling methods), fish nests, & aerial macrophyte surveys.

Table 2

Variance Component & Precision Estimates for Current AMP Program Developed from Year 2000 Monitoring Data

Linked	Measure	Primary Sampling U	Strata	Samples/ Stratum	Dates	CV's Within Strata Median	Low	High	CV's Across Dates Median	Low	High	RSE of Stratum Mean/ Event Median	Low	High	RSE of Lake Mean / Event Median	Low	High	RSE of Lake Mean/Yr Median	Low	High
Trib Macroinv.	NYSDEC Score	Site	1	4		0.20	0.07	0.41				0.10	0.04	0.21						
Trib Macroinv.	HBI Score	Site	1	4		0.16	0.06	0.62				0.08	0.03	0.31						
Trib Macroinv.	% Oligochaetes	Site	1	4		0.42	0.11	0.87				0.21 *	0.06	0.43						
Littoral Macroinv.	NYSDEC Score	Stratum	5	36		0.22	0.13	0.38				0.04	0.02	0.06	0.02	0.01	0.03			
Littoral Macroinv.	HBI Score	Stratum	5	36		0.45	0.20	0.48				0.08	0.03	0.08	0.03	0.01	0.04			
Littoral Macroinv.	Invert Density /m2	Stratum	5	36		0.61	0.46	0.70				0.10	0.06	0.12	0.05	0.03	0.05			
Littoral Macroinv.	% Oligochaetes	Stratum	5	36		0.15	0.04	0.52				0.03	0.01	0.09	0.01	0.00	0.04			
Littoral Macrophytes	Avg % Cover Out to End of Growth	Stratum	5	4		0.91	0.68	1.04				0.45 *	0.34	0.52	0.20 *	0.15	0.23			
Littoral Macrophytes	Freq of Occurrence to End of Growth	Stratum	5	4		0.69	0.21	0.79				0.34 *	0.10	0.39	0.15	0.05	0.18			
Littoral Macrophytes	Avg % Cover Out to 4m Depth	Stratum	5	4		1.01	0.70	1.11				0.50 *	0.35	0.56	0.23 *	0.16	0.25			
Littoral Macrophytes	Freq of Occurrence to 4m Depth	Stratum	5	4		0.85	0.31	1.83				0.42 *	0.16	0.91	0.19	0.07	0.41			
Littoral Macrophytes	Avg Biomass out to End of Growth	Stratum	5	4		1.39	0.63	1.93				0.69 *	0.32	0.96	0.31 *	0.14	0.43			
Littoral Algae	Avg % Cover Out to End of Growth	Stratum	5	4		0.92	0.72	0.95				0.46 *	0.36	0.48	0.21 *	0.16	0.21			
Littoral Algae	Avg % Cover Out to 4m Depth	Stratum	5	4		1.12	0.61	1.45				0.56 *	0.30	0.72	0.25 *	0.14	0.32			
Littoral Algae	Avg Biomass out to End of Growth	Stratum	5	4		1.56	0.67	2.00				0.78 *	0.34	1.00	0.35 *	0.15	0.45			
Littoral Fish Larvae	Species Abundance	Stratum - Species	5	3	7	1.74	0.94	3.00				1.00 *	0.54	1.73	0.45 *	0.24	0.77			
Littoral Fish Larvae	Total Abundance	Stratum	5	3	7	0.96	0.52	1.52	0.56	0.16	0.84	0.56 *	0.30	0.88	0.25 *	0.13	0.39	0.23 *	0.08	0.35
Littoral Fish Larvae	Species Richness	Stratum	5	3	7	0.39	0.27	0.63	0.30	0.14	0.35	0.23 *	0.16	0.36	0.10	0.07	0.16	0.12	0.06	0.15
Littoral Fish Larvae	Species Diversity	Stratum	5	3	7	0.33	0.23	0.53	0.19	0.14	0.22	0.19	0.13	0.31	0.09	0.06	0.14	0.08	0.06	0.10
Pelagic Fish Larvae	Species Abundance	Basin - Species	2	4	7	1.35	0.61	3.36	1.38			0.67 *	0.31	1.66	0.48 *	0.22	1.19			
Pelagic Fish Larvae	Total Abundance	Basin	2	4	7	0.89	0.55	1.49	1.17	0.78	1.76	0.44 *	0.27	0.74	0.31 *	0.19	0.53	0.46 *	0.30	0.69
Pelagic Fish Larvae	Species Richness	Basin	2	4	7	0.35	0.22	0.98	0.54	0.36	0.82	0.17	0.11	0.49	0.12	0.08	0.35	0.21 *	0.14	0.34
Pelagic Fish Larvae	Species Diversity	Basin	2	4	7	0.32	0.27	0.46	0.18	0.12	0.27	0.16	0.13	0.23	0.11	0.09	0.16	0.08	0.06	0.12
Juvenile Fish	Species Abundance	Stratum - Species	5	9	7	1.71	1.07	2.98				0.57 *	0.36	0.99	0.25 *	0.16	0.44			
Juvenile Fish	Total Abundance	Stratum	5	9	7	1.23	0.85	1.81	1.06	0.78	1.78	0.41 *	0.28	0.60	0.18	0.13	0.27	0.41 *	0.30	0.68
Juvenile Fish	Species Richness	Stratum	5	9	7	0.71	0.41	1.07	0.48	0.37	0.69	0.24 *	0.14	0.36	0.11	0.06	0.16	0.19	0.14	0.27
Juvenile Fish	Species Diversity	Stratum	5	9	7	0.84	0.46	1.56	0.25	0.13	0.41	0.28 *	0.15	0.52	0.13	0.07	0.23	0.11	0.06	0.18
Littoral Adult Fish	Gamefish Abundance	Stratum	5	4.8		0.79	0.56	1.32				0.36 *	0.26	0.60	0.16	0.12	0.27			
Littoral Adult Fish	Gamefish Species Richness	Stratum	5	4.8		0.39	0.27	0.69				0.18	0.12	0.32	0.08	0.06	0.14			
Littoral Adult Fish	Gamefish Species Diversity	Stratum	5	4.8		0.34	0.20	0.43				0.15	0.09	0.19	0.07	0.04	0.09			
Littoral Adult Fish	Gamefish Normalized Richness	Stratum	5	4.8		0.38	0.29	0.45				0.17	0.13	0.21	0.08	0.06	0.09			
Littoral Adult Fish	All Fish Abundance	Stratum	5	2.4		0.38	0.09	1.03				0.25 *	0.06	0.66	0.11	0.03	0.30			
Littoral Adult Fish	All Fish Richness	Stratum	5	2.4		0.20	0.07	0.31				0.13	0.05	0.20	0.06	0.02	0.09			
Littoral Adult Fish	All Fish Species Diversity	Stratum	5	2.4		0.20	0.06	0.69				0.13	0.04	0.45	0.06	0.02	0.20			
Littoral Adult Fish	All Fish Normalized Richness	Stratum	5	2.4		0.14	0.08	0.44				0.09	0.05	0.28	0.04	0.02	0.13			
Phytoplankton	Division Abundance	Site - Division	1	1	20				1.12	0.72	1.92							0.25 *	0.16	0.43
Phytoplankton	Total Abundance	Site	1	1	20				0.84	0.58	0.97							0.19	0.13	0.22
Phytoplankton	Division Biomass	Site - Division	1	1	20				1.12	0.67	2.04							0.25 *	0.15	0.46
Phytoplankton	Total Biomass	Site	1	1	20				1.01	0.83	1.36							0.23 *	0.19	0.30
Zooplankton	Species Abundance	Site - Species	1	1	20				0.89	0.54	1.37							0.20	0.12	0.31
Zooplankton	Total Abundance	Site	1	1	20				0.72	0.71	0.75							0.16	0.16	0.17
Zooplankton	Species Biomass	Site - Species	1	1	20				0.92	0.56	2.20							0.21 *	0.13	0.49
Zooplankton	Total Biomass	Site	1	1	20				0.70	0.63	0.86							0.16	0.14	0.19

Strata = number of lake regions; not applicable to phytoplankton or trib macroinvertebrate monitoring

Samples / Stratum = number of samples per primary sampling unit planned for 2002 & subsequent monitoring

CV's with strata treated as replicates in computing mean over primary sampling unit; median, low, high = 50th, 10th, 90th percentiles of year 2000 data

RSE of stratum mean = relative standard error of stratum (or site mean for phytoplankton & trib macroinvertebrates); computed from median, low, high CV estimates

RSE of lake mean = relative standard error of lake mean computed from stratum means & standard errors; assumes strata weighted equally; computed from median, low, high CV estimates

Species Diversity = shannon-weaver diversity index; Normalized Richness = (Richness - 1) / Log (Total Count)

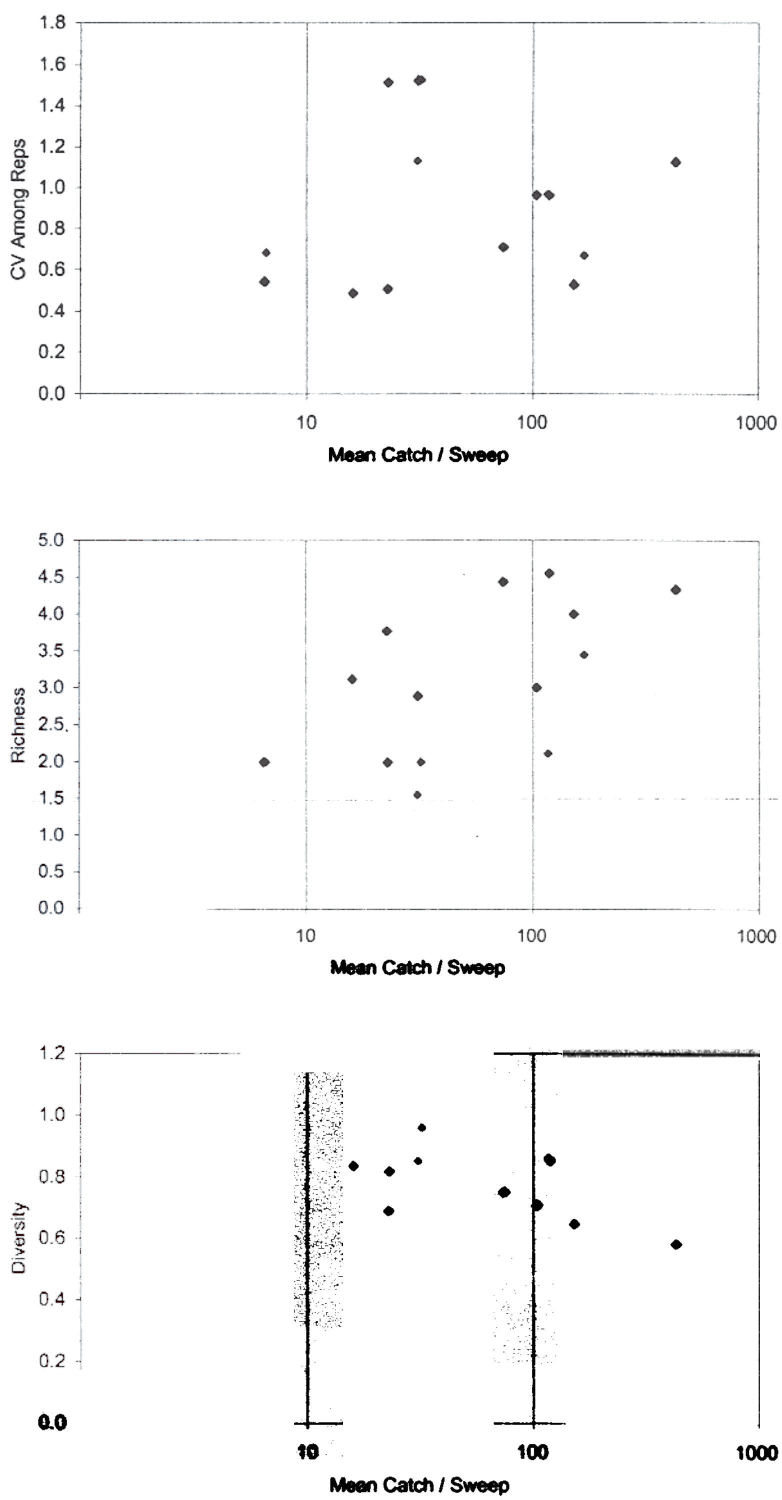
* Median RSE estimate exceeds AMP criterion = 0.2

Table 3
Summary of Precision & Power Estimates

Variable	Averaging Scale Space	Time	AMP 10%	AMP 50%	AMP 90%	2X Reps 50%
Relative Standard Error of Mean (%)						
Trib Macroinv NYSDEC	Station	Event	5%	12%	19%	9%
Lit Macroinv NYSDEC	Stratum	Event	2%	4%	6%	3%
Lit Macroinv Dens.	Stratum	Event	8%	10%	11%	7%
Macrophyte Cover	Lake	Event	17%	21%	24%	15%
Phytoplankton	Station	Year	21%	25%	30%	25%
Zooplankton	Station	Year	25%	30%	36%	29%
Lit Larvae Rich.	Lake	Event	8%	12%	15%	8%
Lit Larvae	Lake	Event	16%	26%	37%	19%
Pel Larvae Rich.	Lake	Event	10%	21%	32%	15%
Pel Larvae	Lake	Event	22%	35%	49%	25%
Juvenile Rich.	Lake	Event	7%	11%	15%	8%
Juveniles	Lake	Event	14%	20%	25%	14%
Adult Fish Rich.	Lake	Event	3%	5%	8%	4%
Adult Gamefish	Lake	Event	13%	19%	25%	14%
Increase Detectable with 80% Confidence (%)						
Trib Macroinv NYSDEC	Station	Event	40%	59%	78%	55%
Lit Macroinv NYSDEC	Stratum	Event	32%	51%	70%	51%
Lit Macroinv Dens.	Stratum	Event	39%	56%	74%	53%
Macrophyte Cover	Lake	Event	59%	72%	88%	62%
Phytoplankton	Station	Year	46%	56%	67%	55%
Zooplankton	Station	Year	53%	63%	73%	61%
Lit Larvae Rich.	Lake	Year	27%	39%	52%	39%
Lit Larvae	Lake	Year	37%	51%	66%	49%
Pel Larvae Rich.	Lake	Year	43%	54%	67%	53%
Pel Larvae	Lake	Year	72%	93%	119%	92%
Juvenile Rich.	Lake	Year	39%	50%	62%	50%
Juveniles	Lake	Year	71%	92%	117%	91%
Adult Fish Rich.	Lake	Event	23%	36%	49%	35%
Adult Gamefish	Lake	Event	36%	48%	61%	42%
Linear Trend Detectable with 80% Confidence (% / yr)						
Trib Macroinv NYSDEC	Station	Event	5.1%	7.5%	10.0%	7.0%
Lit Macroinv NYSDEC	Stratum	Event	2.8%	4.4%	6.0%	4.3%
Lit Macroinv Dens.	Stratum	Event	3.3%	4.8%	6.3%	4.5%
Macrophyte Cover	Lake	Event	-			
Phytoplankton	Station	Year	7.6%	9.2%	11.0%	9.1%
Zooplankton	Station	Year	8.7%	10.4%	12.0%	10.0%
Lit Larvae Rich.	Lake	Year	4.5%	6.4%	8.6%	6.4%
Lit Larvae	Lake	Year	6.0%	8.4%	10.9%	8.1%
Pel Larvae Rich.	Lake	Year	7.1%	8.9%	11.0%	8.7%
Pel Larvae	Lake	Year	11.8%	15.4%	19.5%	15.1%
Juvenile Rich.	Lake	Year	6.4%	8.2%	10.1%	8.1%
Juveniles	Lake	Year	11.6%	15.1%	19.3%	15.0%
Adult Fish Rich.	Lake	Event	3.7%	5.9%	8.0%	5.8%
Adult Gamefish	Lake	Event	6.0%	7.9%	10.0%	6.9%

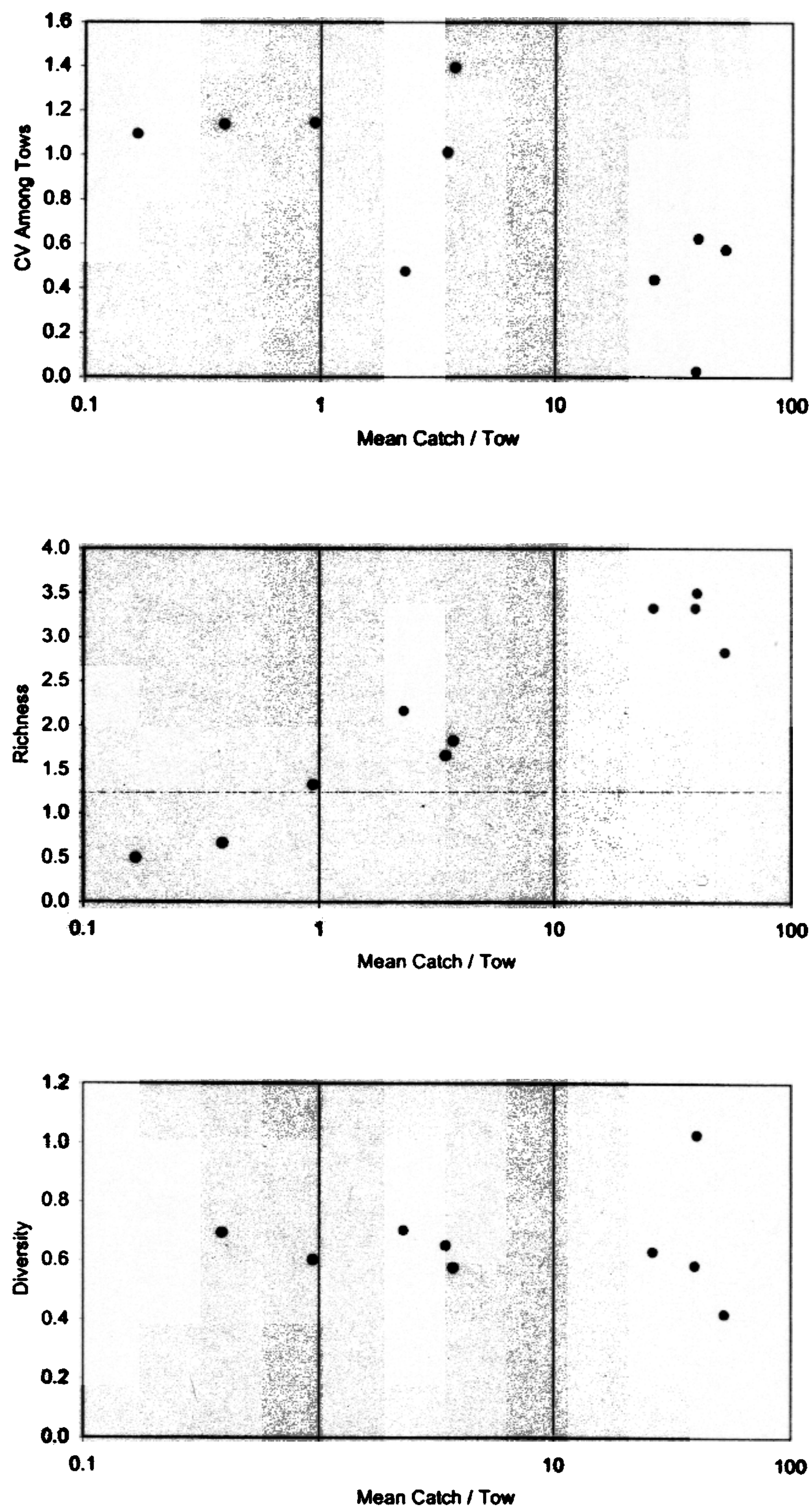
2X Reps = Double number of samples per stratum or station; 2X transects for macrophytes
Metrics are abundance or relative abundance, unless otherwise noted.

Figure 1
Species Richness & Diversity vs. Abundance - Littoral Larvae Data



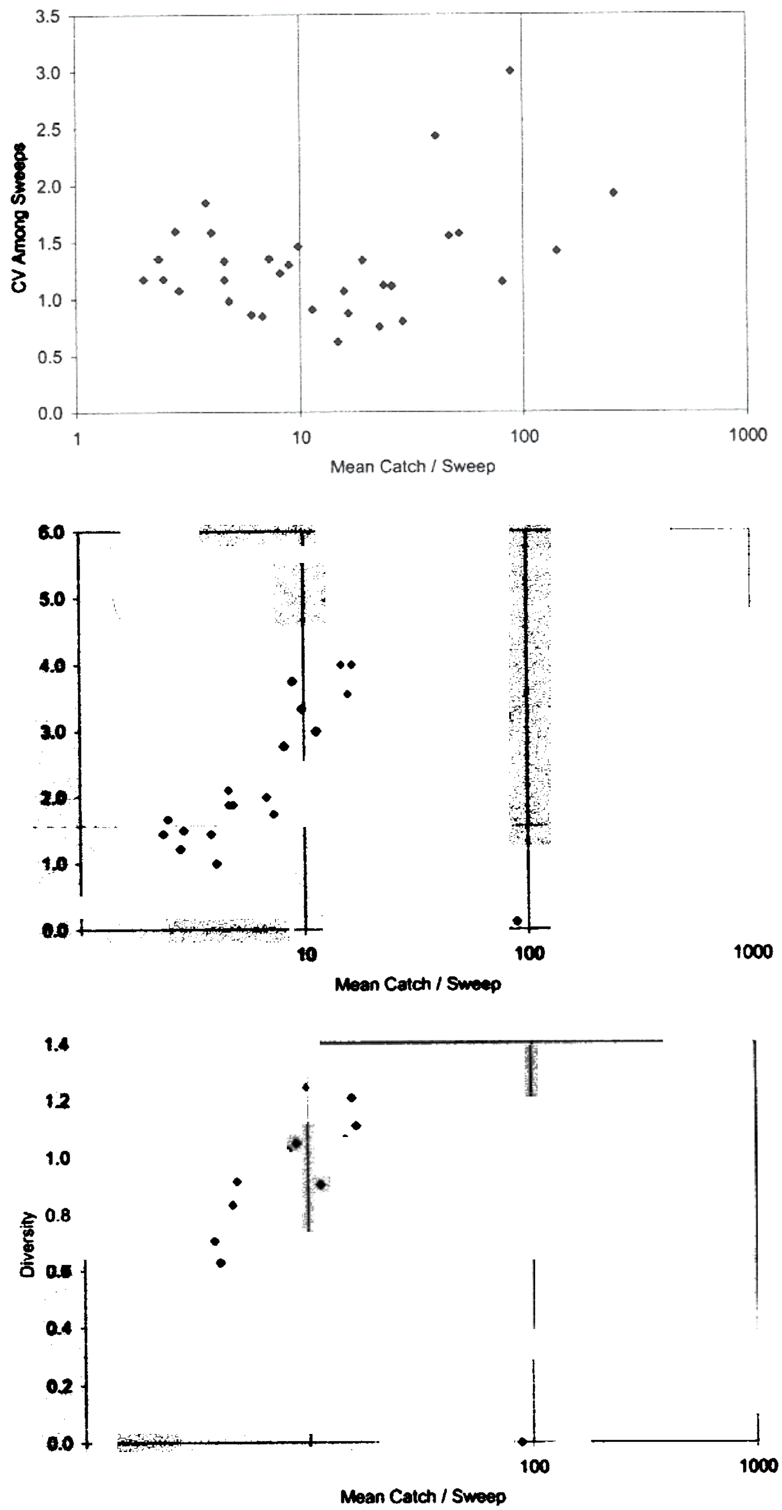
Data points reflect 5 lake strata sampled on each of 3 dates
Richness = average number of species per sweep; Diversity = Shannon-Weaver index

Figure 2
Species Richness & Diversity vs. Abundance - Pelagic Larvae Data



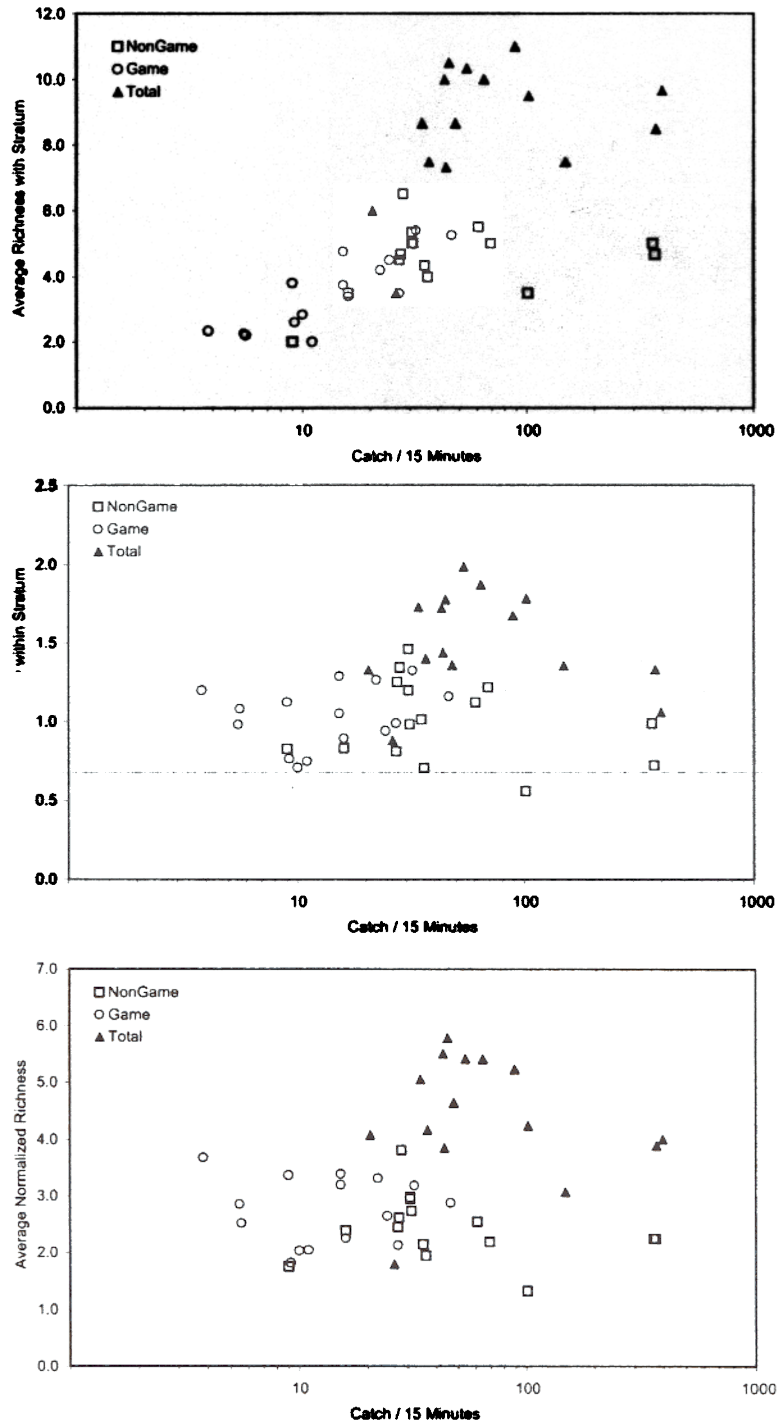
Data points reflect 2 basins (N or S) & 5 samling dates
Richness = average number of species per sweep; Diversity = **Shannon-Weaver index**

Figure 3
Species Richness & Diversity vs. Abundance - Juvenile Fish Data



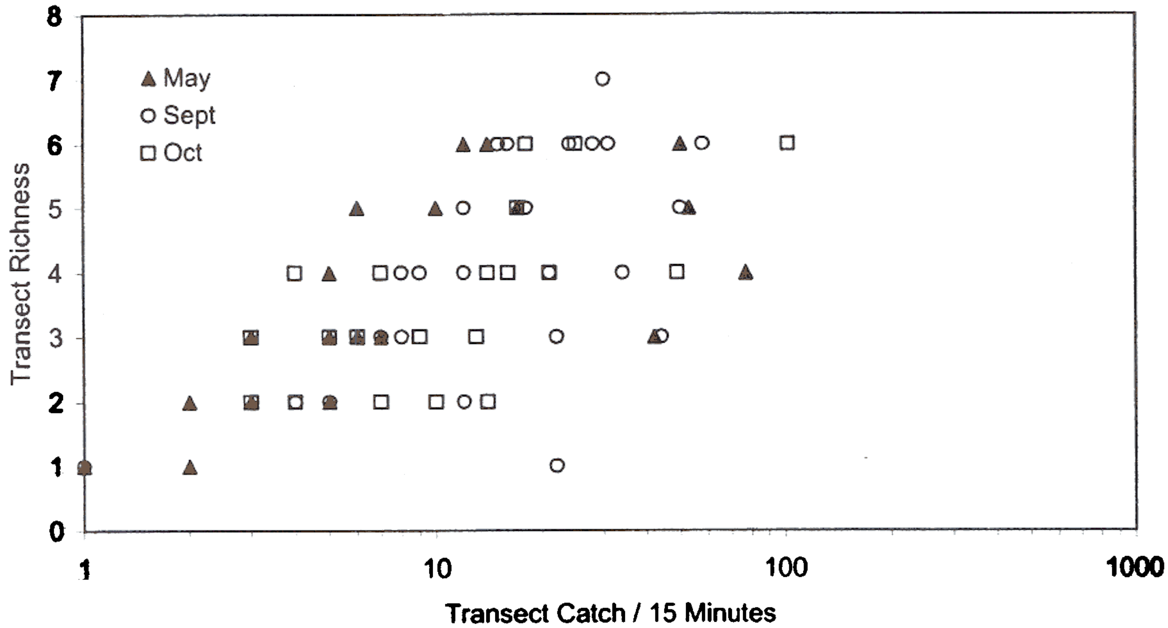
Data points reflect 5 lake strata & 7 sampling events
Richness = average number of species per sweep; Diversity = Shannon-Weaver index

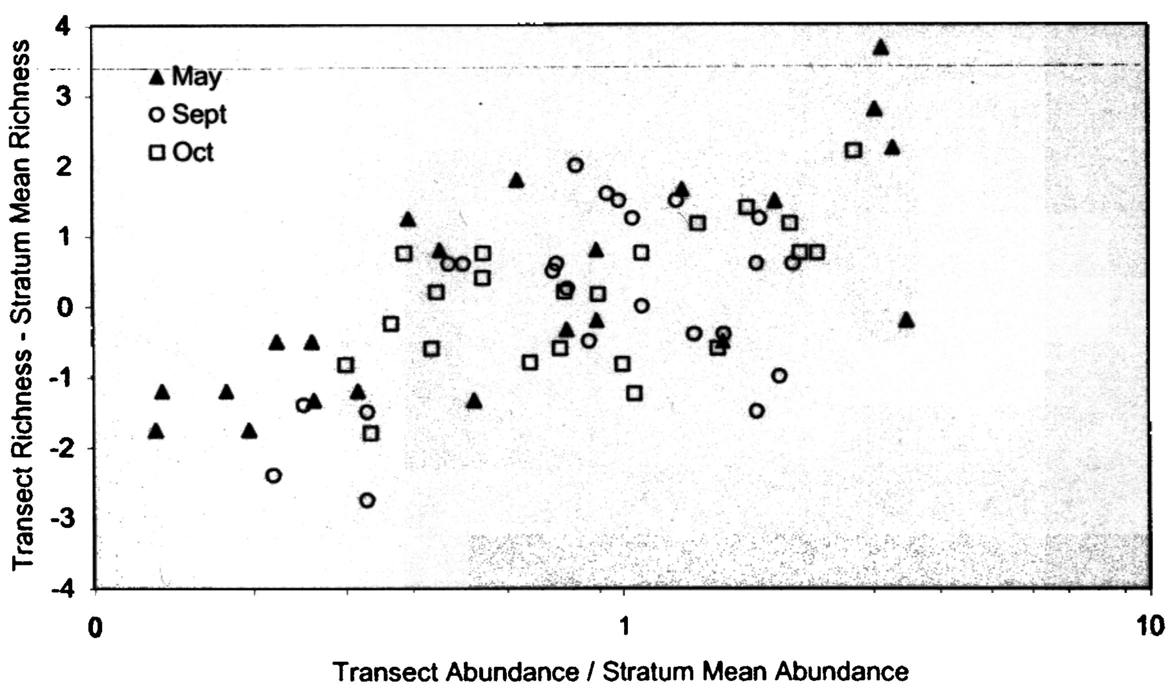
Figure 4
Species Richness & Diversity vs. Abundance - Adult Electrofishing Data



Data points reflect 5 lake strata and 3 sampling events.
Richness = no. of species; Diversity = Shannon-Weaver Index; Normalized Richness = (Richness -1) / Log (Total Count)
Indices computed separately for each transect, then averaged across transects within each stratum

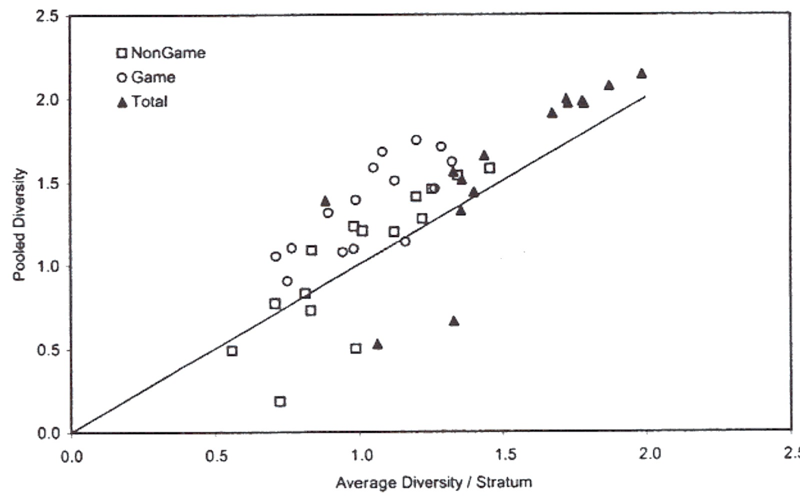
Figure 4A
Richness vs. Abundance by Transect & Date - Adult Gamefish

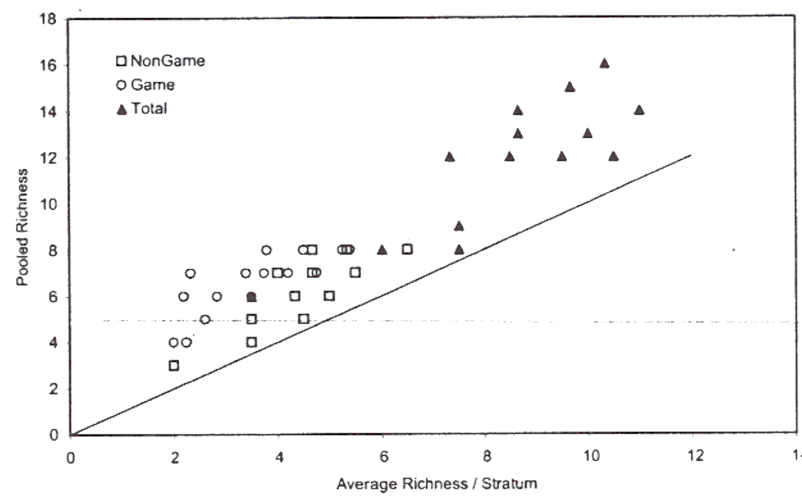


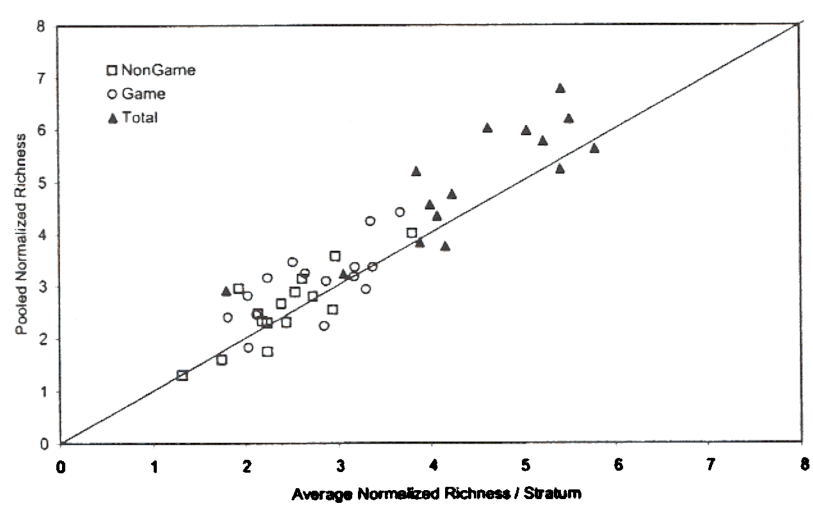


Top Panel:	Raw Data, r = 0.72
Bottom Panel:	Monthly Stratum Means (~Spatial Variations) Removed, r = 0.59

Figure 5
Effect of Pooling Samples on Species Richness & Diversity - Adult Fish

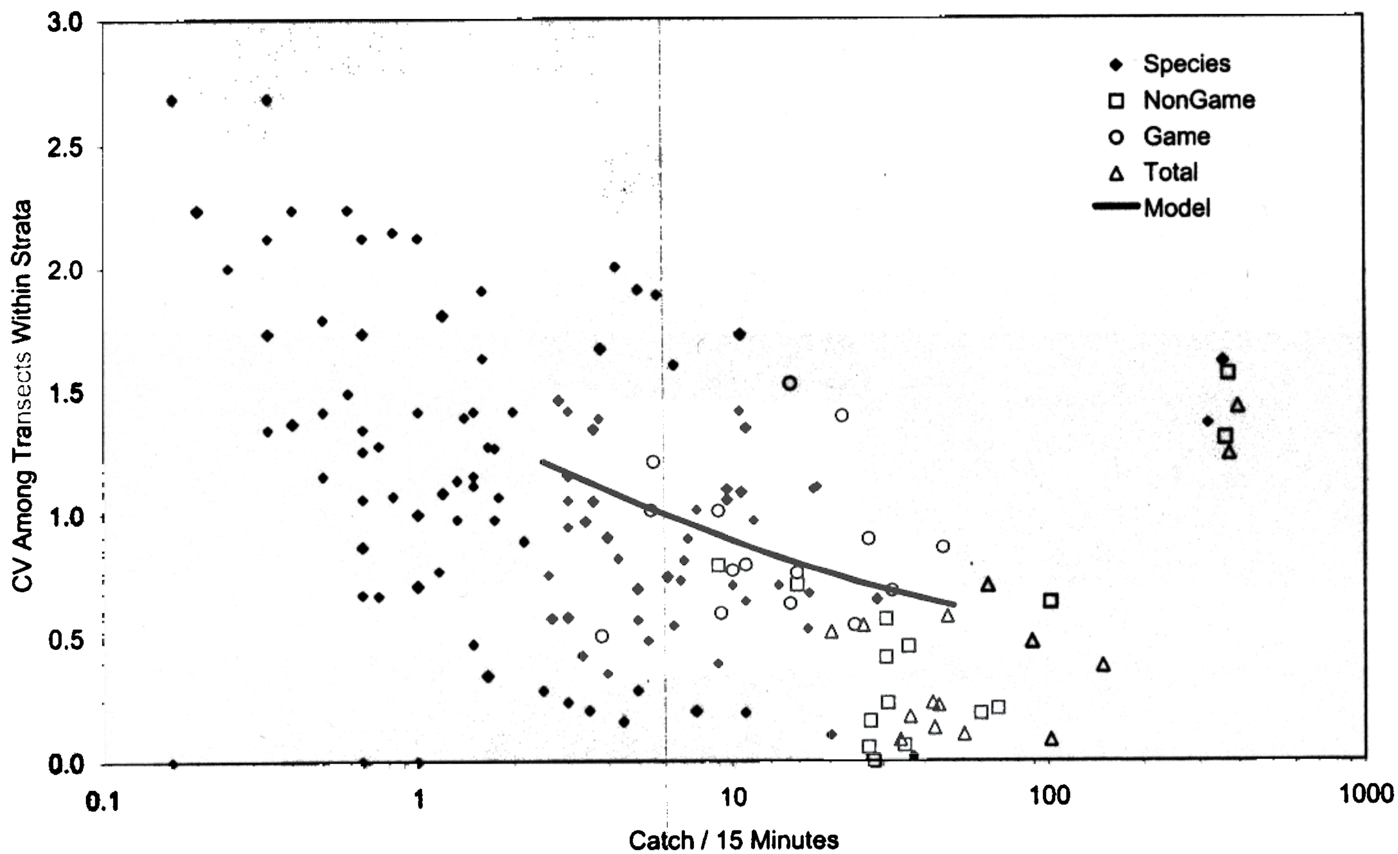






Data points reflect 5 lake strata & 3 sampling events
Pooled values = Diversity & Richness computed after pooling transects within each stratum
Average values = Diversity & Richness computed for each transect, then averaged across transects within each stratum
Richness = no. of species; Diversity = Shannon-Weaver Index; Normalized Richness = (Richness -1) / Log (Total Count)

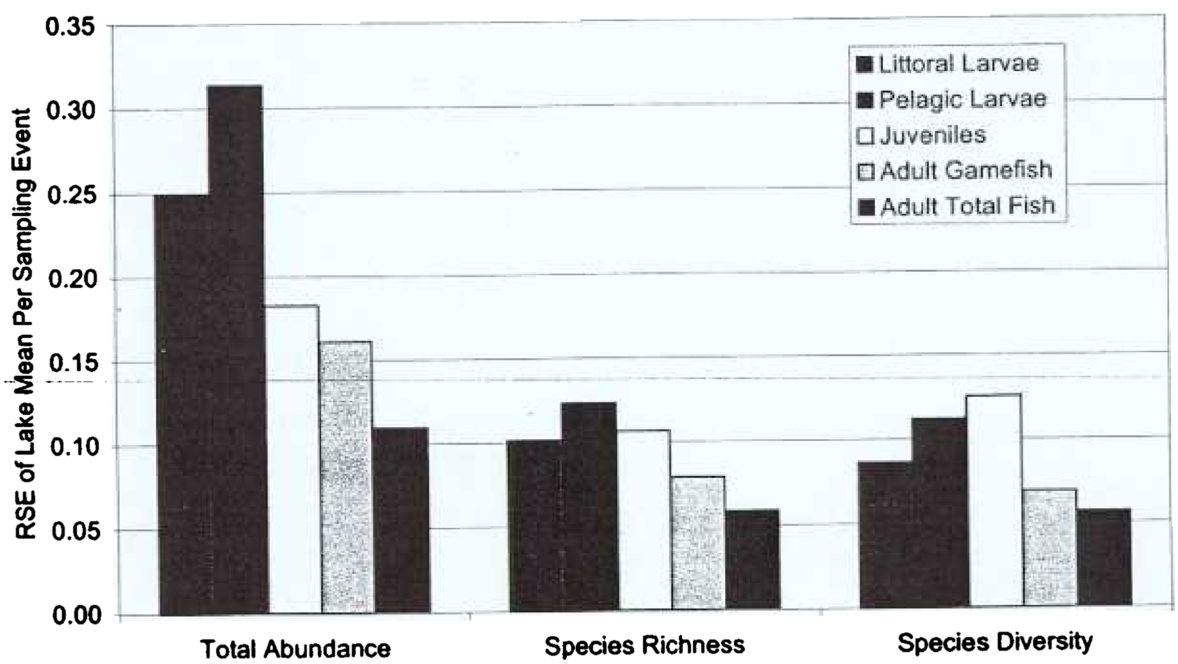
Figure 6
Replicate CV's vs. Abundance for Electrofishing



Model: Regression equation for largemouth bass (Miranda et al, 1996) used to estimate CV's in previous report (Walker, 2000)
Species: CV among transects for individual species
Total Counts: CV among transects for total fish count (gamefish, nongamefish, total fish pooled separately)

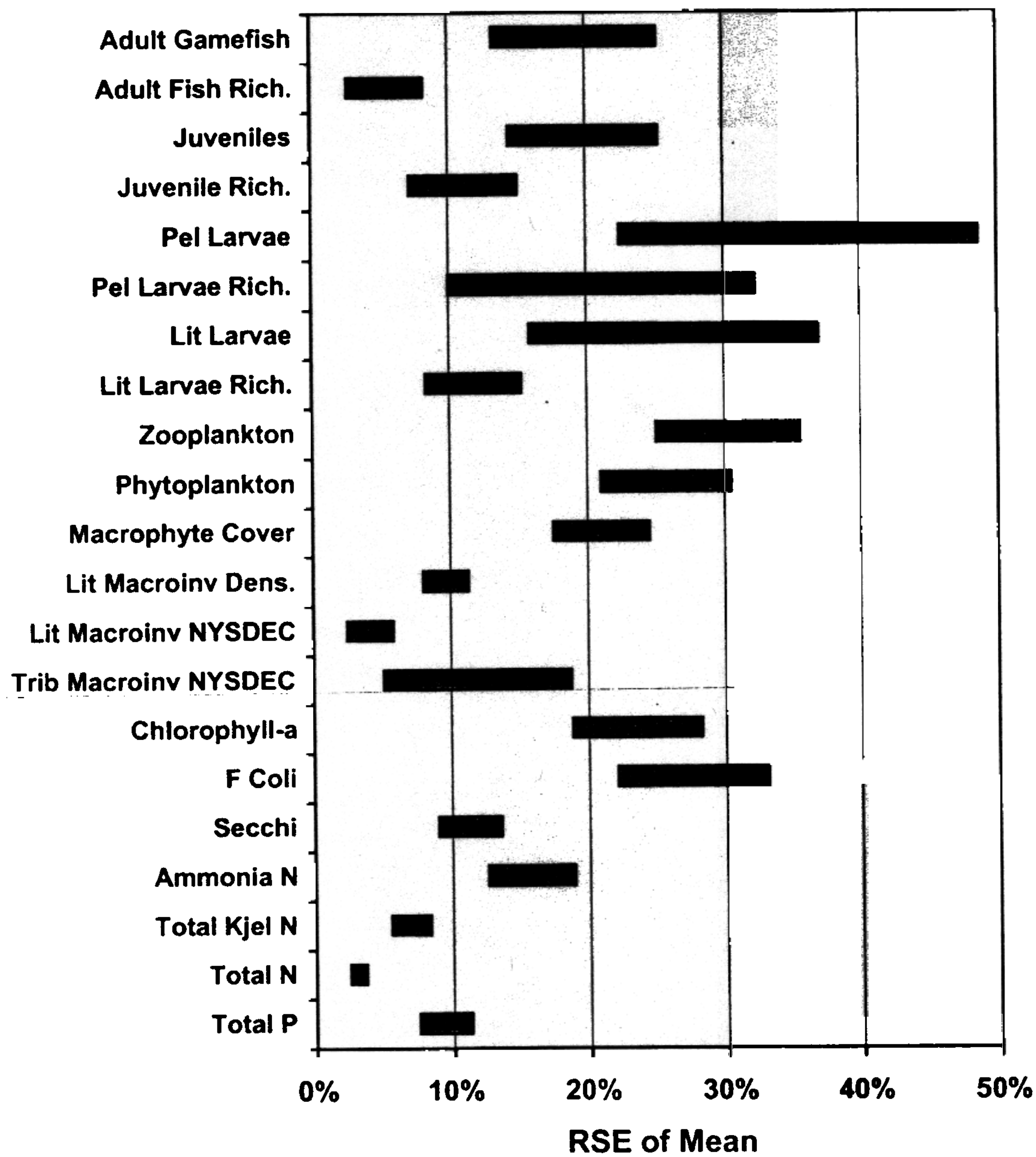
Figure 7

Precision of Fish Abundance, Richness, & Diversity Index Measurements



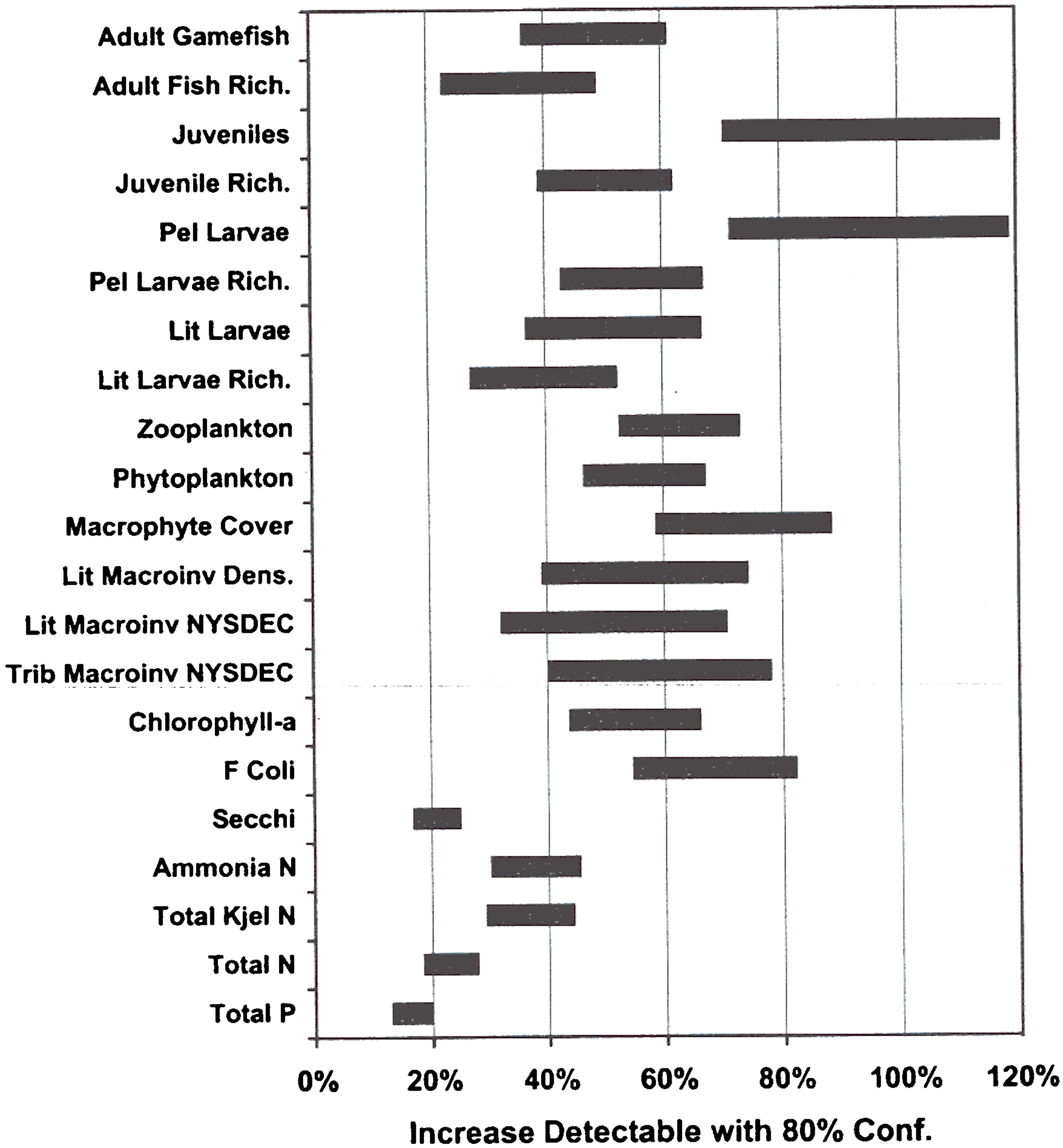
Median estimates from Table 2

Figure 8
Precision Estimates



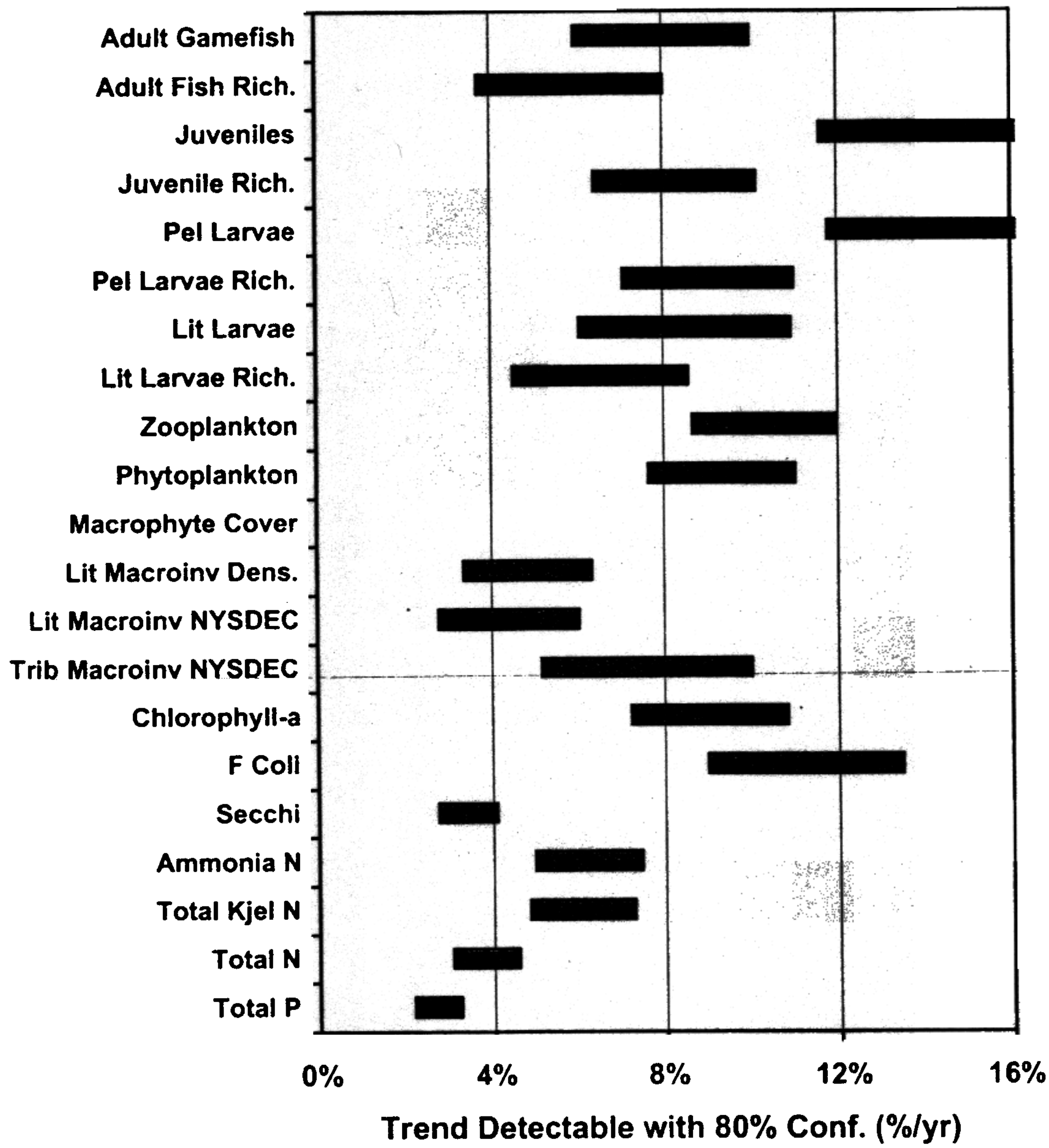
Bars show 10th, 50th, & 90th percentile estimates.
Averaging regimes listed in Table 3

Figure 9
Increases Detectable with 80% Confidence



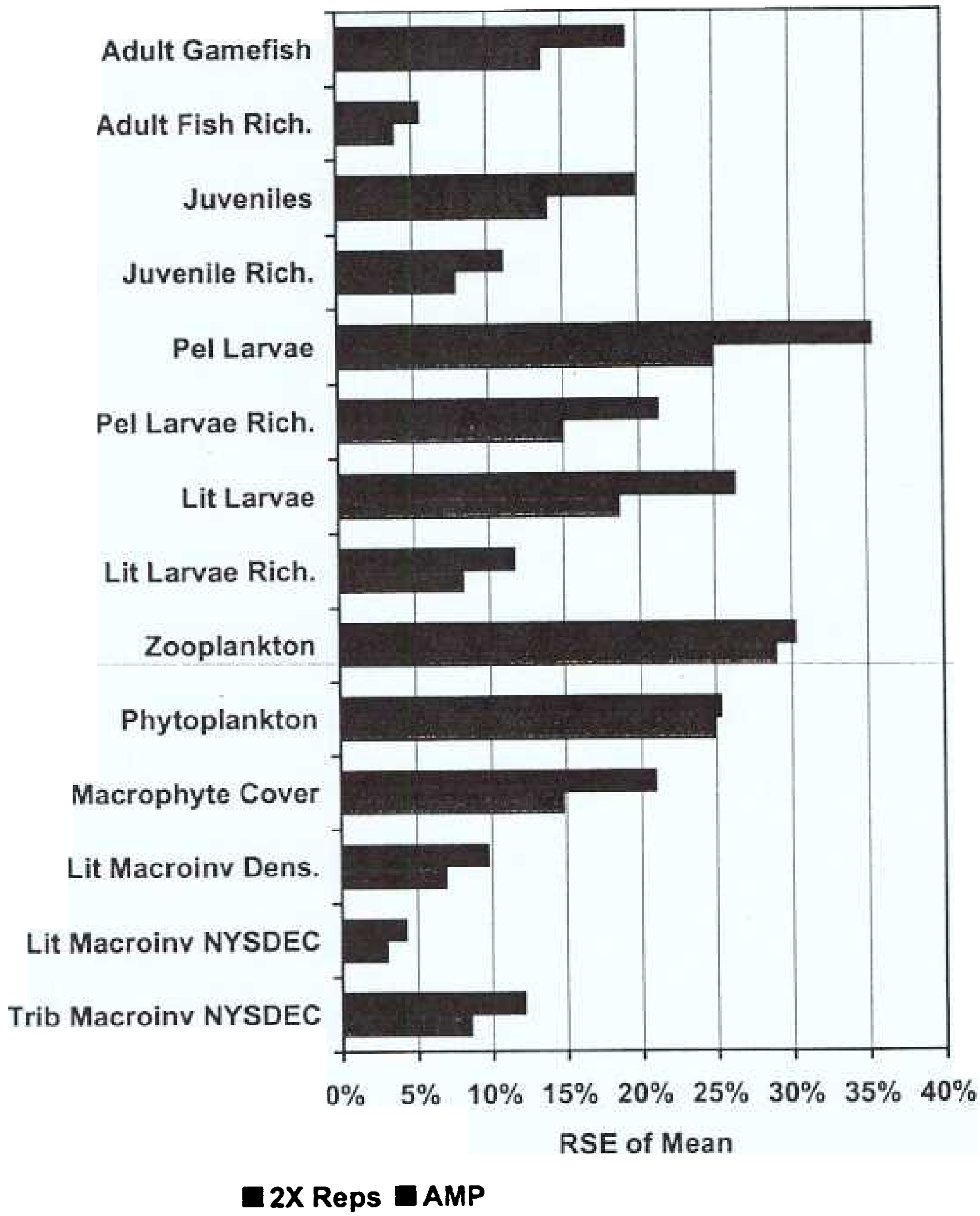
An increase of 100% means a doubling.
Bars show 10th, 50th, & 90th percentile estimates.
Averaging regimes listed in Table 3

Figure 10
Trends Detectable with 80% Confidence



Bars show 10th, 50th, & 90th percentile estimates.
Averaging regimes listed in Table 11

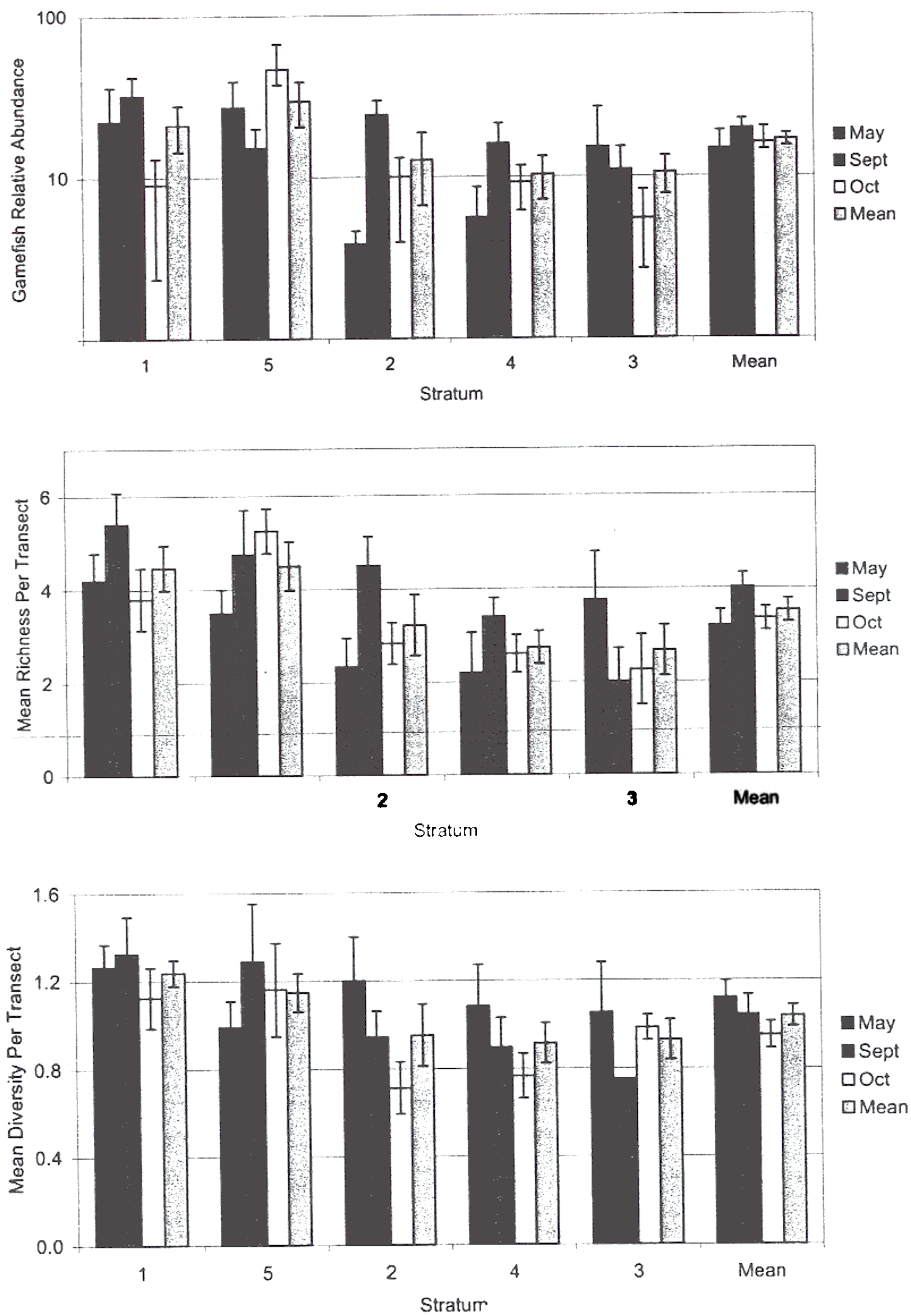
Figure 11
Sensitivity of Precision to Increases in Sampling Frequency



2X Reps = Double number of sites or replicates per stratum or station
Averaging regimes listed in Table 3

Figure 12

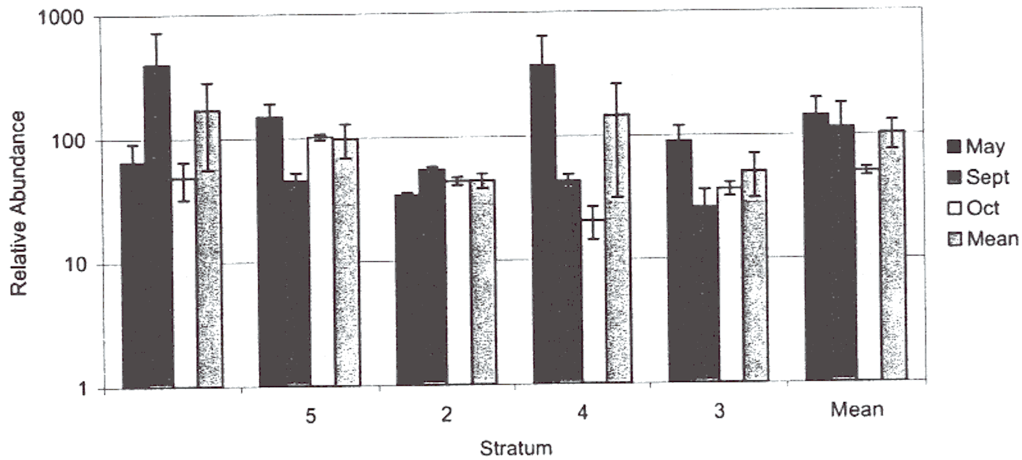
Spatial & Temporal Distribution of Adult Gamefish, Year 2000 Survey

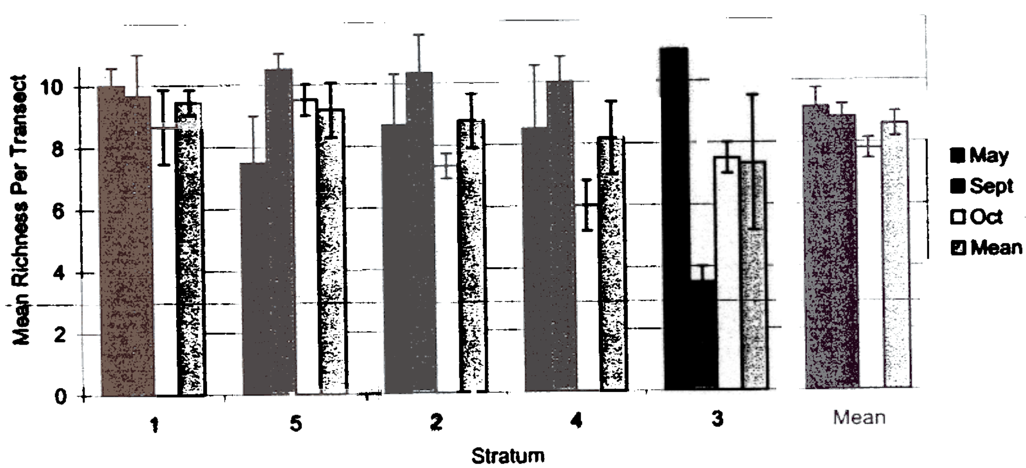


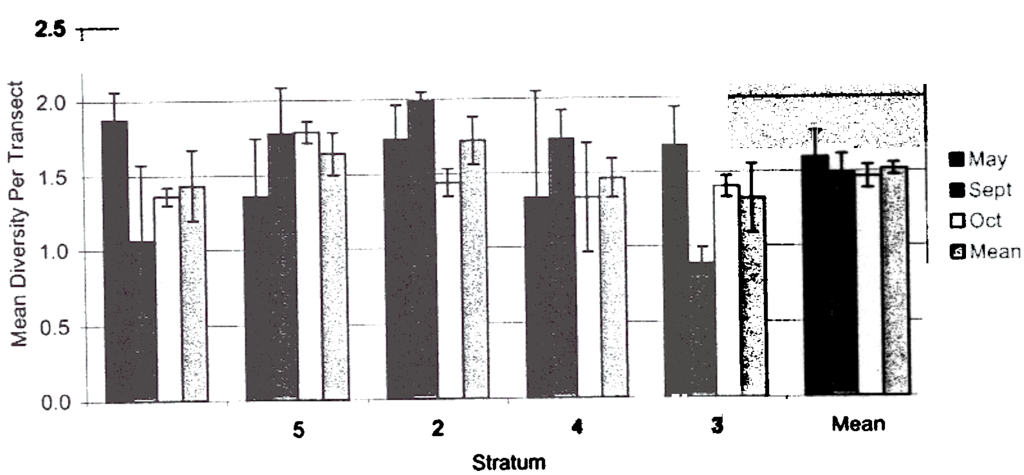
Strata Sorted in North ---> South Direction

Means +/- 1 Standard Error based upon average of 4.8 transects per stratum

Figure 13
Spatial & Temporal Distribution of All Adult Fish, Year 2000 Survey







Strata Sorted in North —> South Direction
Means +/- 1 Standard Error based upon average of 2.4 transects per stratum

Appendix A

Worksheets for Selected Variables & Metrics

Page	Variable	Metric
A-1	Tributary Macroinvertebrates	NYSDEC Score
	Littoral Macroinvertebrates	Density
	Littoral Macroinvertebrates	NYSDEC Score
A-4	Macrophytes	Percent Cover
	Phytoplankton	Density
	Zooplankton	Density
	Littoral Fish Larvae	Species Richness
A-8	Littoral Fish Larvae	Relative Abundance (Catch / Effort)
	Pelagic Fish Larvae	Species Richness
~~A-10~~	~~Pelagic Fish Larvae~~	~~Relative Abundance (Catch / Effort)~~
A-11	Juvenile Fish	Species Richness
	Juvenile Fish	Relative Abundance (Catch / Effort)
A-13	Adult Fish	Species Richness
	Adult GameFish	Relative Abundance (Catch / Effort)

Worksheet for Stream Macroinvertebrates - NYSDEC Index

Method	Kick Samples	
Seasons	Fall	
Sites	10	Onondaga, Ley, Harbor Cks.
Replicates	4	
Interval	2	years
Baseline Years	3	
Metric	NYS DEC Score	
Methodology	Ecologic / NYSDEC Protocol	

Design	Min	Mean	Max	2X Reps	2X Yrs	Notes
Replicates	4	4	4	8	4	
Interval	2	2	2	2	1	
Years in Baseline	3	3	3	3	5	
Variance Components						
Yearly	0.10	0.20	0.30	0.20	0.20	a
Replicates	0.07	0.24	0.41	0.24	0.24	b
Predicted Percentiles	10%	50%	90%	50%	50%	
Site Mean						
RSE of Site Mean	0.05	0.12	0.19	0.09	0.12	
Year-to-Year CV	0.16	0.23	0.31	0.22	0.23	
RSE of Baseline Mean	0.09	0.13	0.18	0.13	0.10	
Power for Det. 25% Increase	0.16	0.23	0.42	0.25	0.44	
Power for Det. 50% Increase	0.44	0.68	0.92	0.73	0.92	
Power for Det. 100% Increase	0.93	0.98	1.00	0.99	1.00	
Incr. Detect. with 80% Conf.	0.40	0.59	0.78	0.55	0.41	
Power for Det. 3%/Yr Trend	0.17	0.24	0.40	0.26	0.29	
~~Power for Det. 5%/Yr Trend~~	~~0.32~~	~~0.49~~	~~0.78~~	~~0.54~~	~~0.58~~	
Power for Det. 10%/Yr Trend	0.80	0.95	1.00	0.97	0.98	
Trend Detect. with 80% Conf.	0.05	0.08	0.10	0.07	0.07	
Upstream / Downstream Contrasts - Yearly						
RSE of Yearly Site Difference	0.07	0.17	0.26	0.12	0.17	
Power for 25% Difference	0.18	0.32	0.91	0.62	0.32	
Power for 50% Difference	0.48	0.82	1.00	0.98	0.82	
Power for 100% Difference	0.94	1.00	1.00	1.00	1.00	
Difference Detect. with 80% Conf.	0.21	0.49	0.75	0.32	0.49	
Upstream / Downstream Contrasts - Baseline						
RSE of Baseline Difference	0.13	0.19	0.25	0.18	0.15	
Power for 25% Difference	0.24	0.34	0.57	0.39	0.50	
Power for 50% Difference	0.60	0.81	0.98	0.87	0.95	
Power for 100% Difference	0.98	1.00	1.00	1.00	1.00	
Difference Detect. with 80% Conf.	0.34	0.49	0.65	0.45	0.37	

References:

a assumed for all bio variables

b Replicate CV's - Year 2000 Monitoring

NYSDEC Score	0.07	to	0.41
HBI Score	0.06	to	0.62
% Oligochaetes	0.11	to	0.87
Assumed Here	0.07	to	0.41

Worksheet for Littoral Macroinvertebrate Density

Method	Dredge	
Seasons	July	
Sites	5	Littoral Zone, 1.5 meters depth, Ponar Samples
Replicates	36	per site
Interval	3	
Baseline Years	3	
Metric	Density, #/m2	
Methodology	EcoLogic (2001)	

Design	Min	Mean	Max	2X Reps	2X Yrs	Notes
Replicates	36	36	36	72	36	
Interval	3	3	3	3	1	
Years in Baseline	3	3	3	3	5	
Variance Components						
Yearly	0.10	0.20	0.30	0.20	0.20	a
Replicates	0.46	0.58	0.70	0.58	0.58	b
Predicted Percentiles	10%	50%	90%	50%	50%	
Site Mean						
RSE of Site Mean	0.08	0.10	0.11	0.07	0.10	
Year-to-Year CV	0.16	0.22	0.30	0.21	0.22	
RSE of Baseline Mean	0.09	0.13	0.17	0.12	0.10	
Power for Det. 25% Increase	0.17	0.25	0.44	0.27	0.47	
Power for Det. 50% Increase	0.48	0.72	0.93	0.76	0.94	
Power for Det. 100% Increase	0.94	0.99	1.00	0.99	1.00	
Incr. Detect. with 80% Conf.	0.39	0.56	0.74	0.53	0.39	
Power for Det. 3%/Yr Trend	0.30	0.45	0.72	0.49	0.31	
Power for Det. 5%/Yr Trend	0.62	0.83	0.97	0.86	0.62	
Power for Det. 10%/Yr Trend	0.98	1.00	1.00	1.00	0.98	
Trend Detect. with 80% Conf.	0.03	0.05	0.06	0.05	0.06	

References:

a assumed for all bio variables

b CV's Among Replicates for Year 2000 Data

NYSDEC Score	0.13	to	0.38
HBI Score	0.20	to	0.48
Invert Density /m2	0.46	to	0.70
% Oligochaetes	0.04	to	0.52
Assumed Here	0.46	to	0.70

Worksheet for Littoral Macroinvertebrates - NYSDEC Index

Method	Dredge	
Seasons	July	
Sites	5	Littoral Zone, 1.5 meters depth, Ponar Samples
Replicates	36	per site
Interval	3	
Baseline Years	3	
Metric	NYSDEC Score, HBI Score, Density, % Oligochaetes	
Methodology	EcoLogic (2001)	

Design	Min	Mean	Max	2X Reps	2X Yrs	Notes
Replicates	36	36	36	72	36	
Interval	3	3	3	3	1	
Years in Baseline	3	3	3	3	5	
Variance Components						
Yearly	0.10	0.20	0.30	0.20	0.20	a
Replicates	0.13	0.25	0.38	0.25	0.25	b
Predicted Percentiles	10%	50%	90%	50%	50%	
Site Mean						
RSE of Site Mean	0.02	0.04	0.06	0.03	0.04	
Year-to-Year CV	0.13	0.20	0.28	0.20	0.20	
RSE of Baseline Mean	0.07	0.12	0.16	0.12	0.09	
Power for Det. 25% Increase	0.18	0.28	0.59	0.29	0.53	
Power for Det. 50% Increase	0.52	0.78	0.97	0.79	0.96	
Power for Det. 100% Increase	0.96	0.99	1.00	0.99	1.00	
Incr. Detect. with 80% Conf.	0.32	0.51	0.70	0.51	0.36	
Power for Det. 3%/Yr Trend	0.32	0.51	0.85	0.52	0.35	
Power for Det. 5%/Yr Trend	0.66	0.88	0.99	0.89	0.68	
Power for Det. 10%/Yr Trend	0.99	1.00	1.00	1.00	0.99	
Trend Detect. with 80% Conf.	0.03	0.04	0.06	0.04	0.06	

References:

a assumed for all bio variables

b CV's Among Replicates for Year 2000 Data

NYSDEC Score	0.13	to	0.38
HBI Score	0.20	to	0.48
Invert Density /m2	0.46	to	0.70
% Oligochaetes	0.04	to	0.52
Assumed Here	0.13	to	0.38

Worksheet for Macrophyte Percent Cover

Method	Field Survey	
Seasons	August	
Strata	5	defined based upon substrate
Transects	4	at random within each stratum
Subplots Per Transect	60	randomly selected within 10 meter zones
Interval	5	measured in two years over entire program
Baseline Years	1	2000
Metric	% Cover Out to 4 Meters Depth & End of Growth	
Methodology	EcoLogic, Inc. (2001)	

Design	Min	Mean	Max	2X Trans	2X Sub	2X Yrs	Notes
Strata	5	5	5	5	5	5	
Subplots	60	60	60	60	120	60	
Transects	4	4	4	8	8	4	
Interval	5	5	5	5	5	3	
Years in Baseline	1	1	1	1	1	2	
Variance Components							
Yearly	0.10	0.20	0.30	0.20	0.20	0.20	a
Transects	0.70	0.90	1.11	0.90	0.90	0.90	c
Strata	0.00	0.00	0.00	0.00	0.00	0.00	b
Subplots	1.11	1.82	2.53	1.82	1.82	1.82	d
Predicted Percentiles	10%	50%	90%	50%	50%	50%	
Stratum Mean							
RSE of Transect Mean	0.16	0.23	0.31	0.23	0.17	0.23	
RSE of Stratum Mean	0.39	0.47	0.55	0.33	0.33	0.47	
Year-to-Year CV	0.44	0.51	0.59	0.39	0.38	0.51	
RSE of Baseline Mean	0.44	0.51	0.59	0.39	0.38	0.36	
Power for Det. 25% Increase	0.11	0.12	0.14	0.16	0.16	0.17	
Power for Det. 50% Increase	0.21	0.25	0.30	0.36	0.37	0.40	
Power for Det. 100% Increase	0.51	0.62	0.73	0.83		0.87	
Incr. Detect. with 80% Conf.	1.10	1.27	1.48	0.96		0.89	
Lake Mean							
RSE of Lake Mean	0.17	0.21	0.24	0.15	0.15	0.21	
Year-to-Year CV	0.24	0.29	0.36	0.25	0.25	0.29	
RSE of Baseline Mean	0.24	0.29	0.36	0.25	0.25	0.20	
Power for 25% Increase	0.17	0.22	0.28	0.26	0.26	0.34	
Power for 50% Increase	0.41	0.53	0.68	0.64	0.65	0.79	
Power for 100% Increase	0.88	0.96	1.00	0.99	0.99	1.00	
Incr. Detect. with 80% Conf.	0.59	0.72	0.88	0.62	0.62	0.51	

References:

a assumed for all bio variables

b assume spatial variance factored out by stratified sampling plan

c Onondaga Lake Year 2000 Macrophyte Survey
CV across Transects within Strata

Avg % Cover Out to End of Growth	0.68	to	1.04
Avg % Cover Out to 4m Depth	0.70	to	1.11
Used Here	0.70	to	1.11

d CV Across Subplots with Transects

Avg % Cover Out to End of Growth	0.99	to	2.28
Avg % Cover Out to 4m Depth	1.11	to	2.53
Used Here	1.11	to	2.53

Worksheet for Phytoplankton

Method	Tygon Tube	
Frequency	Biweekly	
Dates Per year	10	May-Sept
Sites	1	Lake South, Quarterly at North
Depths	1	Epilimnetic Composite
Replicates		
Sampling Interval	1	Years
Baseline Years	5	
Metric	Organism Counts, May-Sept, Lake South	
Methodology	OCDSS / Dr. Ed Mills	

Design	Min	Mean	Max	2X Reps	2X Dates	Notes
Replicates	1	1	1	2	1	
Dates	10	10	10	10	20	
Interval	1	1	1	1	1	
Years in Baseline	5	5	5	5	5	
Variance Components						
Yearly	0.10	0.20	0.30	0.20	0.20	a
Dates	0.58	0.77	0.97	0.77	0.77	b
Replicates	0.10	0.20	0.30	0.20	0.20	c
Predicted Percentiles	10%	50%	90%	50%	50%	
Site Mean						
RSE of Daily Mean	0.12	0.20	0.28	0.14	0.20	
~~RSE of Yearly Mean~~	~~0.21~~	~~0.25~~	~~0.30~~	~~0.25~~	~~0.18~~	
Year-to-Year CV	0.27	0.32	0.38	0.32	0.27	
RSE of Baseline Mean	0.12	0.14	0.17	0.14	0.12	
Power for Det. 25% Increase	0.21	0.27	0.36	0.28	0.36	
Power for Det. 50% Increase	0.57	0.72	0.85	0.72	0.85	
Power for Det. 100% Increase	0.97	0.99	1.00	0.99	1.00	
Incr. Detect. with 80% Conf.	0.46	0.56	0.67	0.55	0.47	
Power for Det. 3%/Yr Trend	0.16	0.19	0.24	0.20	0.24	
Power for Det. 5%/Yr Trend	0.29	0.37	0.49	0.38	0.48	
Power for Det. 10%/Yr Trend	0.73	0.85	0.94	0.86	0.94	
Trend Detect. with 80% Conf.	0.08	0.09	0.11	0.09	0.08	

References:

a assumed for all bio variables

b 2000 Lake Data, May-Sept, Lake South Epilimnetic Composites

Total Abundance	0.58	to	0.97
Total Biomass	0.83	to	1.36
Use Here	0.58	to	0.97

c Assumed Rep CV as for Chla **0.1** to **0.3**

Worksheet for Zooplankton

Method	Vertical Net Tow	
Frequency	Biweekly	
Dates per Years	10	For May-Sept; also sampled in other months
Sites	1	Lake South, Quarterly at Lake North
Depths	1	Epilimnetic Composite
Replicates		
Sampling Interval	1	Years
Baseline Years	5	
Metric	Organism Counts, May-Sept, Total Zooplankton, Lake South	
Methodology	OCDWEP / Dr. Ed Mills	

Design	Min	Mean	Max	2X Reps	2X Dates	Notes
Replicates		1	1	2	1	
Dates	10	10	10	10	20	
Interval		1	1	1	1	
Years in Baseline	5	5	5	5	5	
Variance Components						
Yearly	0.10	0.20	0.30	0.20	0.20	a
Dates	0.65	0.87	1.09	0.87	0.87	b
Replicates	0.30	0.40	0.50	0.40	0.40	c
Predicted Percentiles	10%	50%	90%	50%	50%	
Site Mean						
RSE of Daily Mean	0.32	0.40	0.48	0.28	0.40	
RSE of Yearly Mean	0.25	0.30	0.36	0.29	0.21	
Year-to-Year CV	0.30	0.36	0.42	0.35	0.29	
RSE of Baseline Mean	0.14	0.16	0.19	0.16	0.13	
Power for Det. 25% Increase	0.19	0.23	0.30	0.24	0.31	
Power for Det. 50% Increase	0.51	0.62	0.76	0.65	0.79	
Power for Det. 100% Increase	0.95	0.98	0.99	0.99	1.00	
Incr. Detect. with 80% Conf.	0.53	0.63	0.73	0.61	0.51	
Power for Det. 3%/Yr Trend	0.15	0.17	0.21	0.18	0.22	
Power for Det. 5%/Yr Trend	0.26	0.32	0.41	0.33	0.43	
Power for Det. 10%/Yr Trend	0.66	0.77	0.89	0.80	0.91	
Trend Detect. with 80% Conf.	0.09	0.10	0.12	0.10	0.08	

References:

a assumed for all bio variables

b Year 2000 Zooplankton Data, Variability Across Dates within Seasons

Total Abundance	0.71	to	0.75
Total Biomass	0.63	to	0.86
Used Here	0.71	to	1.20
Adjusted for Replicate Var	0.65	to	1.09

c Downing et al, 1987 — Regression of Replicate Variance against zooplankton count; 1,189 sets of replicate samples compiled from literater

Count (#/L)	CV			
Count	1	10	100	1000
CV	0.54	0.46	0.38	0.32
Assumed range:		0.3	to	0.5

Worksheet for Littoral Fish Larvae

Method	Larval Fish Seine
Seasons	Biweekly, May-Aug
Strata	5
Replicates per Stratum	3
Dates Per year	7
Sampling Interval	1 years
Baseline Years	5
Metric	Total Abundance, # / m^3 filtered
Methodology	NYSDEC Percid Sampling Manual

Design	Min	Mean	Max	2X Reps	Notes
Strata	5	5	5	5	
Replicates	3	3	3	6	
Dates	7	7	7	7	
Interval	1	1	1	1	
Years in Baseline	5	5	5	5	
Variance Components					
Yearly	0.10	0.20	0.30	0.20	a
Dates	0.16	0.50	0.84	0.50	c
Replicates	0.52	1.02	1.52	1.02	b
Predicted Percentiles	10%	50%	90%	50%	
Stratum Mean					
RSE of Event Mean	0.35	0.59	0.83	0.42	
RSE of Yearly Mean	0.20	0.29	0.39	0.25	
Year-to-Year CV	0.27	0.35	0.45	0.32	
RSE of Baseline Mean	0.12	0.16	0.20	0.14	
Power for Det. 25% Increase	0.18	0.24	0.35	0.28	
Power for Det. 50% Increase	0.46	0.64	0.84	0.73	
Power for Det. 100% Increase	0.93	0.98	1.00	0.99	
Incr. Detect. with 80% Conf.	0.47	0.62	0.79	0.55	
Power for Det. 3%/Yr Trend	0.14	0.17	0.24	0.20	
Power for Det. 5%/Yr Trend	0.24	0.33	0.48	0.38	
Power for Det. 10%/Yr Trend	0.61	0.79	0.94	0.86	
Trend Detect. with 80% Conf.	---	---	0.13	0.09	
Lake Mean					
RSE of Event Mean	0.16	0.26	0.37	0.19	
RSE of Yearly Mean	0.13	0.21	0.31	0.20	
Year-to-Year CV	0.21	0.29	0.38	0.28	
RSE of Baseline Mean	0.09	0.13	0.17	0.13	
			0.00		
Power for 25% Increase	0.22	0.31	0.50	0.33	
Power for 50% Increase	0.58	0.79	0.95	0.81	
Power for 100% Increase	0.97	1.00	1.00	1.00	
Incr. Detect. with 80% Conf.	0.37	0.51	0.66	0.49	
Power for Det. 3%/Yr Trend	0.16	0.22	0.33	0.22	
Power for Det. 5%/Yr Trend	0.29	0.43	0.66	0.45	
Power for Det. 10%/Yr Trend	0.17	0.23	0.36	0.24	
Trend Detect. with 80% Conf.	0.06	0.08	0.11	0.08	

References:

a assumed for all bio variables

Onondaga Lake Year 2000 Data (Icthy. & EcoLOgic, 2001)
Replicate CV's

Species Abundance	0.94	to	3.00
Total Abundance	0.52	to	1.52
Species Richness	0.27	to	0.63
Used Here	0.52	to	1.52

Onondaga Lake Year 2000 Data (Icthy. & EcoLOgic, 2001)
Date CV's

Total Abundance	0.16	to	0.84
Species Richness	0.14	to	0.35
Used Here	0.16	to	0.84

Worksheet for Littoral Fish Larvae Species Richness

Method	Larval Fish Seine
Seasons	Biweekly, May-Aug
Strata	5
Replicates per Stratum	3
Dates Per year	7
Sampling Interval	1 years
Baseline Years	5
Metric	Average Number of Species Per Sample
Methodology	NYSDEC Percid Sampling Manual

Design	Min	Mean	Max	2X Reps	Notes
Strata	5	5	5	5	
Replicates	3	3	3	6	
Dates	7	7	7	7	
Interval	1	1	1	1	
Years in Baseline	5	5	5	5	
Variance Components					
Yearly	0.10	0.20	0.30	0.20	a
Dates	0.14	0.25	0.35	0.25	c
Replicates	0.27	0.45	0.63	0.45	b
Predicted Percentiles	10%	50%	90%	50%	
Stratum Mean					
RSE of Event Mean	0.19	0.26	0.34	0.18	
RSE of Yearly Mean	0.11	0.14	0.17	0.12	
Year-to-Year CV	0.18	0.24	0.31	0.23	
RSE of Baseline Mean	0.08	0.11	0.14	0.10	
Power for Det. 25% Increase	0.28	0.41	0.63	0.44	
Power for Det. 50% Increase	0.74	0.90	0.98	0.92	
Power for Det. 100% Increase	0.99	1.00	1.00	1.00	
Incr. Detect. with 80% Conf.	0.31	0.42	0.54	0.40	
Power for Det. 3%/Yr Trend	0.20	0.28	0.41	0.29	
Power for Det. 5%/Yr Trend	0.39	0.56	0.78	0.59	
~~Power for Det. 10%/Yr Trend~~	~~0.87~~	~~0.97~~	~~1.00~~	~~0.98~~	
Trend Detect. with 80% Conf.	0.05	0.07	0.09	0.07	
Lake Mean					
RSE of Event Mean	0.08	0.12	0.15	0.08	
RSE of Yearly Mean	0.08	0.10	0.13	0.10	
Year-to-Year CV	0.16	0.23	0.30	0.22	
RSE of Baseline Mean	0.07	0.10	0.13	0.10	
			0.00		
Power for 25% Increase	0.30	0.46	0.73	0.47	
Power for 50% Increase	0.77	0.93	0.99	0.93	
Power for 100% Increase	1.00	1.00	1.00	1.00	
Incr. Detect. with 80% Conf.	0.27	0.39	0.52	0.39	
Power for Det. 3%/Yr Trend	0.21	0.30	0.50	0.31	
Power for Det. 5%/Yr Trend	0.41	0.61	0.86	0.62	
Power for Det. 10%/Yr Trend	0.22	0.33	0.55	0.34	
Trend Detect. with 80% Conf.	0.05	0.06	0.09	0.06	

References:

a assumed for all bio variables

b Onondaga Lake Year 2000 Data (Icthy. & EcoLOgic, 2001)

Species Abundance	0.94	to	3.00
Total Abundance	0.52	to	1.52
Species Richness	0.27	to	0.63
Used Here	0.27	to	0.63

Onondaga Lake Year 2000 Data (Icthy. & EcoLOgic, 2001)

Total Abundance	0.16	to	0.84
Species Richness	0.14	to	0.35
Used Here	0.14	to	0.35

Worksheet for Pelagic Larvae Species Richness

Method	Miller High-Speed Trawl	
Seasons	Biweekly, April-Mid August	
Dates Per year	7	
Sites	2	North & South Basins
Depths	1	Integrated 1-9 meters
Replicates	4	tows/basin
Sampling Interval	1	Years
Baseline Years	5	
Metric	Average Number of Species Per Sweep	
Methodology	NYSDEC Percid Sampling Manual	

Design	Min	Mean	Max	2X Reps	Notes
Sites	2	2	2	2	
Replicates	4	4	4	8	
Dates	7	7	7	7	
Interval	1	1	1	1	
Years in Baseline	5	5	5	5	
Variance Components					
Yearly	0.10	0.20	0.30	0.20	a
Dates	0.36	0.59	0.82	0.59	b
Replicates	0.22	0.60	0.98	0.60	c
Predicted Percentiles	10%	50%	90%	50%	
Basin Mean					
RSE of Event Mean	0.14	0.30	0.46	0.21	
RSE of Yearly Mean	0.18	0.25	0.31	0.24	
Year-to-Year CV	0.26	0.32	0.40	0.31	
RSE of Baseline Mean	0.12	0.14	0.18	0.14	
Power for Det. 25% Increase	0.21	0.27	0.37	0.29	
Power for Det. 50% Increase	0.55	0.72	0.87	0.75	
Power for Det. 100% Increase	0.97	0.99	1.00	0.99	
Incr. Detect. with 80% Conf.	0.45	0.56	0.69	0.54	
Power for Det. 3%/Yr Trend	0.15	0.19	0.25	0.20	
Power for Det. 5%/Yr Trend	0.28	0.38	0.51	0.40	
Power for Det. 10%/Yr Trend	0.71	0.86	0.95	0.88	
Trend Detect. with 80% Conf.	0.07	0.09	0.11	0.09	
Lake Mean					
RSE of Event Mean	0.10	0.21	0.32	0.15	
RSE of Yearly Mean	0.17	0.24	0.30	0.23	
Year-to-Year CV	0.25	0.31	0.38	0.30	
RSE of Baseline Mean	0.11	0.14	0.17	0.14	
Power for 25% Increase	0.21	0.29	0.40	0.29	
Power for 50% Increase	0.58	0.75	0.89	0.76	
Power for 100% Increase	0.97	0.99	1.00	0.99	
Incr. Detect. with 80% Conf.	0.43	0.54	0.67	0.53	
Power for Det. 3%/Yr Trend	0.16	0.20	0.27	0.21	
Power for Det. 5%/Yr Trend	0.29	0.40	0.54	0.41	
Power for Det. 10%/Yr Trend	0.17	0.21	0.29	0.22	
Trend Detect. with 80% Conf.	0.07	0.09	0.11	0.09	

References:

assumed for all bio variables

b Year 2000 Monitoring Data (Ichty & Ecologic, 2001)

CV's Across Sweeps

Species Richness	0.22	to	0.98
Species Diversity	0.27	to	0.46
Species Abundance	0.61	to	3.36
Total Abundance	0.55	to	1.49
Assumed Here	0.22	to	0.98

Year 2000 Monitoring Data, CV Across Dates

Total Abundance	0.78	to	1.76
Species Richness	0.36	to	0.82
Species Diversity	0.12	to	0.27
Assumed Here	0.78	to	1.76
Assumed Here	0.36	to	0.82

Worksheet for Pelagic Larvae Abundance

Method	Miller High-Speed Trawl	
Seasons	Biweekly, April-Mid August	
Dates Per year	7	
Sites	2	North & South Basins
Depths	1	Integrated 1-9 meters
Replicates	4	tows/basin
Sampling Interval	1	Years
Baseline Years	5	
Metric	Total Abundance, # / m filtered	
Methodology	NYSDEC Percid Sampling Manual	

Design	Min	Mean	Max	2X Reps	Notes
Sites	2	2	2	2	
Replicates	4	4	4	8	
Dates	7	7	7	7	
Interval	1	1	1	1	
Years in Baseline	5	5	5	5	
Variance Components					
Yearly	0.10	0.20	0.30	0.20	a
Dates	0.78	1.27	1.76	1.27	b
Replicates	0.55	1.00	1.49	1.00	c
Predicted Percentiles	10%	50%	90%	50%	
Basin					
RSE of Event Mean	0.32	0.50	0.69	0.35	
RSE of Yearly Mean	0.38	0.52	0.66	0.50	
Year-to-Year CV	0.44	0.55	0.70	0.54	
RSE of Baseline Mean	0.19	0.25	0.31	0.24	
Power for Det. 25% Increase	0.12	0.14	0.18	0.15	
Power for Det. 50% Increase	0.24	0.34	0.48	0.35	
Power for Det. 100% Increase	0.65	0.83	0.94	0.84	
Incr. Detect. with 80% Conf.	0.76	0.96	1.22	0.93	
Power for Det. 3%/Yr Trend	0.10	0.12	0.14	0.12	
Power for Det. 5%/Yr Trend	0.15	0.19	0.25	0.19	
Power for Det. 10%/Yr Trend	0.33	0.46	0.64	0.48	
Trend Detect. with 80% Conf.	0.12	0.16	0.20	0.15	
Lake Mean					
RSE of Event Mean	0.22	0.35	0.49	0.25	
RSE of Yearly Mean	0.36	0.50	0.65	0.49	
Year-to-Year CV	0.41	0.54	0.68	0.53	
RSE of Baseline Mean	0.18	0.24	0.31	0.24	
Power for 25% Increase	0.12	0.15	0.20	0.15	
Power for 50% Increase	0.25	0.35	0.52	0.36	
Power for 100% Increase	0.67	0.84	0.96	0.85	
Incr. Detect. with 80% Conf.	0.72	0.93	1.19	0.92	
Power for Det. 3%/Yr Trend	0.10	0.12	0.15	0.12	
Power for Det. 5%/Yr Trend	0.15	0.19	0.27	0.20	
Power for Det. 10%/Yr Trend	0.10	0.12	0.15	0.12	
Trend Detect. with 80% Conf.	0.12	0.15	0.20	0.15	

References:

assumed for all bio variables

Year 2000 Monitoring Data (Ichty & Ecologic, 2001)
CV's Across Sweeps

Species Richness	0.22	to	0.98
Species Diversity	0.27	to	0.46
Species Abundance	0.61	to	3.36
Total Abundance	0.55	to	1.49
Assumed Here	0.55	to	1.49

c Year 2000 Monitoring Data, CV Across Dates

Total Abundance	0.78	to	1.76
Species Richness	0.36	to	0.82
Species Diversity	0.12	to	0.27
Assumed Here	0.78	to	1.76

Worksheet for Juvenile Fish Richness

Method	Seine	
Seasons	Every Three Weeks, May-October	
Dates Per Year	7	
Strata	5	
Replicates per stratum	9	3 sites x 3 reps
Sampling Interval	1	Years
Baseline Years	5	
Metric	Average Number of Species Per Sweep	
Methodology	NYSDEC Centrarchids Sampling Manual	

Strata	5	5	5	5	
Replicates	9	9	9	18	
Dates	7	7	7	7	
Interval	1	1	1	1	
Years in Baseline	5	5	5	5	
Variance Components	**Min**	**Mean**	**Max**	**2X Reps**	**Notes**
Yearly	0.10	0.20	0.30	0.20	a
Dates	0.37	0.53	0.69	0.53	c
Replicates	0.41	0.74	1.07	0.74	h
Predicted Percentiles	**10%**	**50%**	**90%**	**50%**	
Stratum Mean					
RSE of Event Mean	0.16	0.25	0.34	0.17	
RSE of Yearly Mean	0.18	0.22	0.27	0.21	
Year-to-Year CV	0.24	0.30	0.36	0.29	
RSE of Baseline Mean	0.11	0.13	0.16	0.13	
Power for Det. 25% Increase	0.23	0.30	0.42	0.32	
Power for Det. 50% Increase	0.61	0.77	0.90	0.79	
Power for Det. 100% Increase	0.98	1.00	1.00	1.00	
Incr. Detect. with 80% Conf.	0.42	0.52	0.63	0.51	
Power for Det. 3%/Yr Trend	0.17	0.21	0.28	0.22	
Power for Det. 5%/Yr Trend	0.31	0.42	0.56	0.43	
Power for Det. 10%/Yr Trend	0.77	0.90	0.97	0.91	
Trend Detect. with 80% Conf.	0.07	0.09	0.10	0.08	
Lake Mean					
RSE of Event Mean	0.07	0.11	0.15	0.08	
RSE of Yearly Mean	0.16	0.20	0.25	0.20	
Year-to-Year CV	0.22	0.29	0.35	0.28	
RSE of Baseline Mean	0.10	0.13	0.16	0.13	
Power for 25% Increase	0.24	0.32	0.46	0.32	
Power for 50% Increase	0.64	0.80	0.93	0.81	
Power for 100% Increase	0.98	1.00	1.00	1.00	
Incr. Detect. with 80% Conf.	0.39	0.50	0.62	0.50	
Power for Det. 3%/Yr Trend	0.17	0.22	0.30	0.22	
Power for Det. 5%/Yr Trend	0.33	0.44	0.61	0.45	
Power for Det. 10%/Yr Trend	0.18	0.24	0.33	0.24	
Trend Detect. with 80% Conf.	0.06	0.08	0.10	0.08	

References:

a assumed for all bio variables

b Year 2000 Monitoring Data (Ichty & Ecologic, 2001)

CV's Across Sweeps Within Strata

Species Abundance	1.07	to	2.98
Total Abundance	0.85	to	1.81
Species Richness	0.41	to	1.07
Species Diversity	0.46	to	1.56
Used Here	0.41	to	1.07

Year 2000 Monitoring Data (Ichty & Ecologic, 2001)

CV Across Dates Within Strata

Total Abundance	0.78	to	1.78
Species Richness	0.37	to	0.69
Species Diversity	0.13	to	0.41
Used Here	0.37	to	0.69

Worksheet for Juvenile Fish Abundance

Method	Seine
Seasons	Every Three Weeks, May-October
Dates Per Year	7
Strata	5
Replicates per stratum	9 3 reps at 3 sites)
Sampling Interval	1 Years
Baseline Years	5
Metric	Relative Abundance, catch per unit effort
Methodology	NYSDEC Centrarchids Sampling Manual

Strata	5	5	5	5	
Replicates	9	9	9	18	
Dates	7	7	7	7	
Interval	1	1	1	1	
Years in Baseline	5	5	5	5	
Variance Components	Min	Mean	Max	2X Reps	**Notes**
Yearly	0.10	0.20	0.30	0.20	a
Dates	0.78	1.28	1.78	1.28	c
Replicates	0.85	1.33	1.81	1.33	b
Predicted Percentiles	10%	50%	90%	50%	
Stratum Mean					
RSE of Event Mean	**0.32**	**0.44**	**0.57**	**0.31**	
RSE of Yearly Mean	**0.38**	**0.51**	**0.66**	**0.50**	
Year-to-Year CV	**0.43**	**0.55**	**0.69**	**0.54**	
RSE of Baseline Mean	**0.19**	**0.25**	**0.31**	**0.24**	
Power for Det. 25% Increase	**0.12**	**0.14**	**0.19**	**0.15**	
Power for Det. 50% Increase	**0.25**	**0.34**	**0.49**	**0.36**	
Power for Det. 100% Increase	**0.66**	**0.83**	**0.95**	**0.85**	
Incr. Detect. with 80% Conf.	**0.75**	**0.95**	**1.20**	**0.93**	
Power for Det. 3%/Yr Trend	**0.10**	**0.12**	**0.14**	**0.12**	
Power for Det. 5%/Yr Trend	**0.15**	**0.19**	**0.25**	**0.19**	
Power for Det. 10%/Yr Trend	**0.34**	**0.47**	**0.64**	**0.49**	
Trend Detect. with 80% Conf.	**0.12**	**0.16**	**0.20**	**0.15**	
Lake Mean					
RSE of Event Mean	**0.14**	**0.20**	**0.25**	**0.14**	
RSE of Yearly Mean	**0.35**	**0.49**	**0.64**	**0.49**	
Year-to-Year CV	**0.41**	**0.53**	**0.68**	**0.52**	
RSE of Baseline Mean	**0.18**	**0.24**	**0.30**	**0.23**	
Power for 25% Increase	**0.12**	**0.15**	**0.20**	**0.15**	
Power for 50% Increase	**0.25**	**0.36**	**0.53**	**0.37**	
Power for 100% Increase	**0.68**	**0.86**	**0.96**	**0.86**	
Incr. Detect. with 80% Conf.	**0.71**	**0.92**	**1.17**	**0.91**	
Power for Det. 3%/Yr Trend	**0.10**	**0.12**	**0.15**	**0.12**	
Power for Det. 5%/Yr Trend	**0.15**	**0.20**	**0.27**	**0.20**	
Power for Det. 10%/Yr Trend	**0.10**	**0.12**	**0.16**	**0.12**	
Trend Detect. with 80% Conf.	**0.12**	**0.15**	**0.19**	**0.15**	

References:

a **assumed for all bio variables**

Year 2000 Monitoring Data (Ichty & Ecologic, 2001)
CV's Across Sweeps Within Strata

Species Abundance	**1.07**	**to**	**2.98**
Total Abundance	**0.85**	**to**	**1.81**
Species Richness	**0.41**	**to**	**1.07**
Species Diversity	**0.46**	**to**	**1.56**
Used Here	**0.85**	**to**	**1.81**

Year 2000 Monitoring Data (Ichty & Ecologic, 2001)
CV Across Dates Within Strata

Total Abundance	**0.78**	**to**	**1.78**
Species Richness	**0.37**	**to**	**0.89**
Species Diversity	**0.13**	**to**	**0.41**
Used Here	**0.78**	**to**	**1.78**

Worksheet for Adult Littoral Species Richness

Method	Electrofishing	
Seasons	May, September, October	
Total Sites	24	
Strata	5	
Average Sites/Stratum	2.4	Game + nonGame Fish
Sampling Interval	1	Years
Years in Baseline	5	
Metric	Total Species Richness, Average Per 15-Minute Sweep	
Methodology	NYSDEC Percid Sampling Manual	

Design	Low	Mean	High	2X Sites	Notes
Strata	5	5	5	5	
Replicates	2.4	2.4	2.4	4.8	
Interval	1	1	1	1	
Years in Baseline	5	5	5	5	
Variance Components					
Yearly	0.10	0.20	0.30	0.20	a
Sites Within Strata	0.07	0.19	0.31	0.19	b
Predicted Percentiles	10%	50%	90%	50%	
Stratum Mean Per Event					
RSE of Stratum Mean	0.06	0.12	0.19	0.09	
Year-to-Year CV	0.16	0.23	0.31	0.22	
RSE of Baseline Mean	0.07	0.10	0.14	0.10	
Power for Det. 25% Increase	0.29	0.43	0.70	0.48	
Power for Det. 50% Increase	0.75	0.92	0.99	0.94	
Power for Det. 100% Increase	0.99	1.00	1.00	1.00	
Incr. Detect. with 80% Conf.	0.28	0.41	0.53	0.38	
Power for Det. 3%/Yr Trend	0.20	0.29	0.47	0.32	
Power for Det. 5%/Yr Trend	0.40	0.58	0.84	0.63	
Power for Det. 10%/Yr Trend	0.88	0.98	1.00	0.99	
Trend Detect. with 80% Conf.	0.05	0.07	0.09	0.06	
Lake Mean Per Event					
RSE of Lake Mean	0.03	0.05	0.08	0.04	
Year-to-Year CV	0.13	0.21	0.28	0.20	
RSE of Baseline Mean	0.06	0.09	0.13	0.09	
Power for 25% Increase	0.33	0.52	0.86	0.53	
Power for 50% Increase	0.82	0.96	1.00	0.96	
Power for 100% Increase	1.00	1.00	1.00	1.00	
Incr. Detect. with 80% Conf.	0.23	0.36	0.49	0.35	
Power for Det. 3%/Yr Trend	0.23	0.34	0.64	0.35	
Power for Det. 5%/Yr Trend	0.45	0.67	0.95	0.69	
Power for Det. 10%/Yr Trend	0.92	0.99	1.00	0.99	
Trend Detect. with 80% Conf.	0.04	0.06	0.08	0.06	

References:

a assumed for all bio variables

Replicate CV's, Year 2000 Electrofishing Data, Onondaga Lake

Gamefish Species Richness	0.27	to	0.69
Gamefish Species Diversity	0.20	to	0.43
Gamefish Abundance	0.56	to	1.32
All Fish Richness	0.07	to	0.31
All Fish Species Diversity	0.06	to	0.69
All Fish Abundance	0.09	to	1.03
Used Here	0.07	to	0.31

Worksheet for Adult Littoral GameFish Abundance

Method	Electrofishing	
Seasons	May, September, October	
Total Sites	24	
Strata	5	
Average Sites/Stratum	4.8	(2.4 for nongame fish)
Sampling Interval	1 Years	
Years in Baseline	5	
Metric	Catch per Unit Effort	
Methodology	NYSDEC Percid Sampling Manual	

Design	Low	Mean	High	2X Sites	Notes
Strata	5	5	5	5	
Replicates	4.8	4.8	4.8	9.6	
Interval	1	1	1	1	
Years in Baseline	5	5	5	5	
Variance Components					
Yearly	0.10	0.20	0.30	0.20	a
Sites Within Strata	0.56	0.94	1.32	0.94	b
Predicted Percentiles	10%	50%	90%	50%	
Stratum Mean Per Event					
RSE of Stratum Mean	0.30	0.43	0.56	0.30	
Year-to-Year CV	0.36	0.47	0.60	0.36	
RSE of Baseline Mean	0.16	0.21	0.27	0.16	
Power for Det. 25% Increase	0.13	0.17	0.23	0.23	
Power for Det. 50% Increase	0.30	0.43	0.63	0.62	
Power for Det. 100% Increase	0.77	0.91	0.98	0.98	
Incr. Detect. with 80% Conf.	0.63	0.82	1.05	0.63	
Power for Det. 3%/Yr Trend	0.11	0.13	0.17	0.17	
Power for Det. 5%/Yr Trend	0.17	0.22	0.32	0.32	
Power for Det. 10%/Yr Trend	0.41	0.57	0.78	0.77	
Trend Detect. with 80% Conf.	0.10	0.14	0.17	0.10	
Lake Mean Per Event					
RSE of Lake Mean	0.13	0.19	0.25	0.14	
Year-to-Year CV	0.21	0.28	0.35	0.24	
RSE of Baseline Mean	0.09	0.12	0.16	0.11	
Power for 25% Increase	0.24	0.34	0.51	0.41	
Power for 50% Increase	0.65	0.82	0.95	0.90	
Power for 100% Increase	0.99	1.00	1.00	1.00	
Incr. Detect. with 80% Conf.	0.36	0.48	0.61	0.42	
Power for Det. 3%/Yr Trend	0.18	0.23	0.34	0.28	
Power for Det. 5%/Yr Trend	0.33	0.46	0.67	0.56	
Power for Det. 10%/Yr Trend	0.80	0.93	0.99	0.97	
Trend Detect. with 80% Conf.	0.06	0.08	0.10	0.07	

References:

a assumed for all bio variables

b Total Gamefish, Replicate CV's, Year 2000 Electrofishing Data, Onondaga Lake

Gamefish Species Richness	0.27	to	0.69
Gamefish Species Diversity	0.20	to	0.43
Gamefish Abundance	0.56	to	1.32
All Fish Richness	0.07	to	0.31
All Fish Species Diversity	0.06	to	0.69
All Fish Abundance	0.09	to	1.03
Used Here	0.56	to	1.32

Appendix B

Comments on May 2002 Draft Report – Ecologic

Responses in Italics

EcoLogic Memorandum

TO:	Jeanne Powers, OCDWEP; Bill Walker
FROM:	Liz Moran
DATE:	June 3, 2002
RE:	Draft Phase II Statistical Framework Report (dated 5/13/02)

At your request, we have reviewed Dr. Walker's draft report "Update of Statistical Framework for the Onondaga Lake Ambient Monitoring Program Phase II- Biological Monitoring" dated May 13, 2002. Our comments are summarized below.

(1) Bill Walker demonstrates that the shift away from abundance or relative abundance in favor of qualitative indices of ecosystem health would provide improved power for trend detection in the biological community. This finding is good news, as the focus on indices may help overcome the statistical limitations associated with the high year-to-year variability in the biota. It seems that an important task is to identify the suite of indicators that makes the most sense for Onondaga Lake and the tributaries. Candidate indicators are well defined for the macroinvertebrates, and we have a good handle on phytoplankton and zooplankton (as outlined in the restoration goals). We need to focus on defining relevant indicators of the fish community and to reach agreement on how to calculate the metrics for the macrophytes.

(2) Analysis of the fish data confirms that species richness is dependant upon sample size. In theory, increased sampling effort increases the probability of finding a rare species in the assemblage at the same time that the increased effort captures a greater number of organisms. Mark points out that the correlation between abundance and richness may also be a consequence of the central role of habitat quality in fish reproductive success, and the patchiness of habitat quality in the lake. ***[see Figure 4A and additional discussion on page 5]***

Habitat complexity and temporal changes in larvae and young-of-year (YOY) exert a similar influence on the number of individuals and species richness, resulting in the positive correlation observed in Figures 1-4. For example, in electrofishing and seining, areas with complex habitat probably contain both a greater number of individuals and species. When these areas are sampled both the number of individuals and the number of species captured increases. YOY and larval fish (lumped into this discussion as young-fish) are more complex since both the number of individuals and species richness changes during the year.

Early in the year young-fish abundance and richness are zero, that is, no reproduction has taken place. After reproduction occurs, young-fish are recruited to the different sampling gears. Not only does the overall abundance of individuals go up but so does the number of species; therefore, we see a correlation between abundance and species richness. This relationship becomes even stronger when we add in habitat variability (not an issue for pelagic samples).

Appropriate measures to account for the correlation (pooling, using normalized richness, or eliminating data sets with low numbers) should be decided in context of the overall study design and the role of habitat quality. Species richness lakewide is an important metric and one that would be easily communicated to the public. However, the strata were used to define broad categories of habitat type based on wind energy and sediment texture and differences between strata are likely to be driven by the physical characteristics. Comparisons between strata will be illustrative, so pooling to eliminate replicates within strata would not be advisable. ***[see Page 6]***

(3) The estimate of 10 – 30% random year-to-year variability (CV) may be low. As stated, future AMP data will support a direct estimate.

(4) RSE for littoral zone macroinvertebrates is well below the 20% goal of the AMP. We should consider reducing the number of replicate samples, as the time spent sorting these samples is considerable and the cost of identification is high. What is the relative reduction in RSE associated with reducing the number of replicates? ***[reducing the replicates by ½ would increase the abundance RSE from 10% to 15%]***

(5) Conclusion #8 relates to counting all the adult fish in each of the electrofishing transects instead of the alternating all fish/game fish strategy. This recommendation has been made by EcoLogic (original workplan design), IA, and Beak. However, County staff members have concluded that it is not logistically possible to sample the entire lake perimeter for all fish in a timely manner. Now that the electrofishing work plan is down to 2 events perhaps this issue can be revisited.

(6) Macrophyte data analysis. Overall, the observation that the detailed survey will be repeated only once more is highly relevant. Changes in percent cover are more likely to be tracked using the annual aerial photos. Defining the potential habitat is an important task for interpreting the aerial photos as well as calculating the indices from the in-lake detailed surveys. Defining the littoral zone to the 5 m contour would be a conservative way to account for potential increased transparency in the future. This is consistent with NYSDEC designation of the littoral habitat for macrophytes on Irondequoit Bay. If the annual aerial photos become the primary data set, we reiterate our recommendation to include ground-truthing each year.